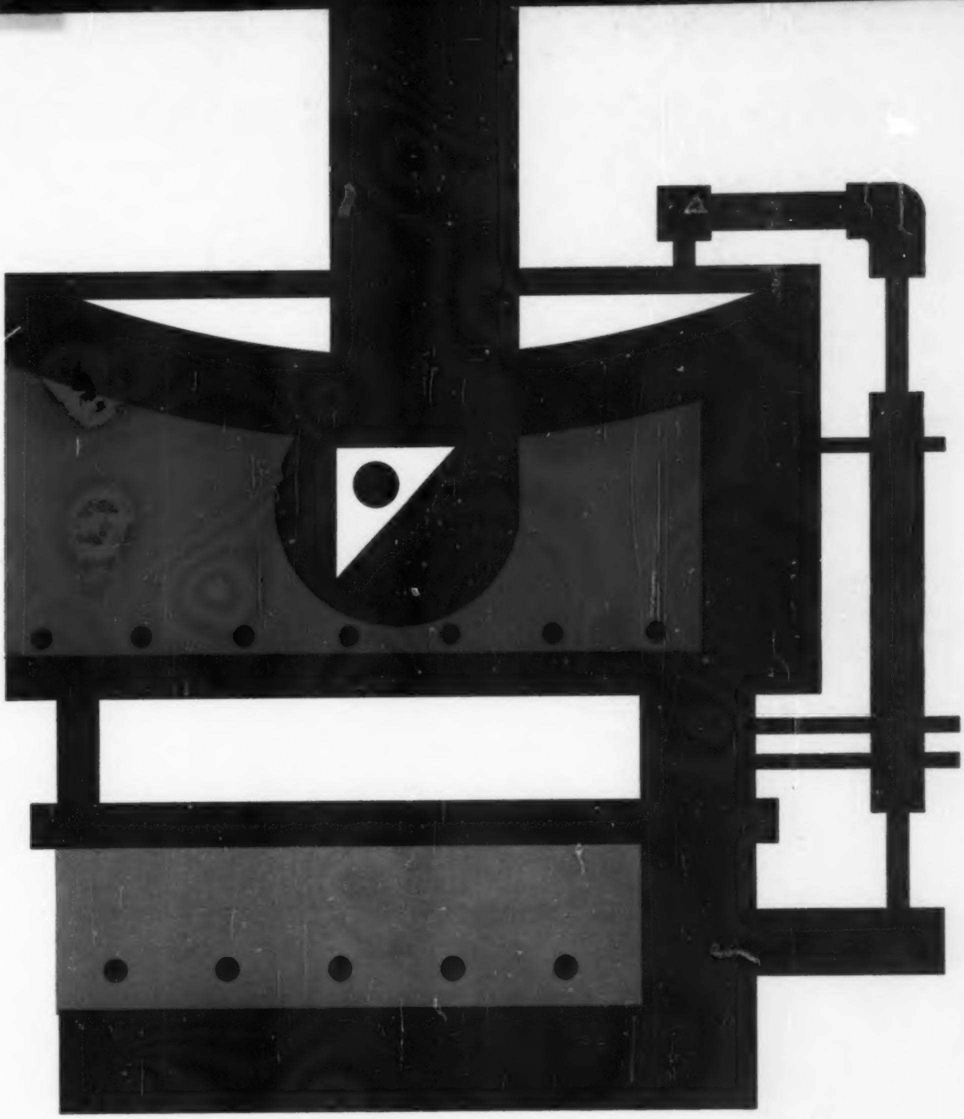
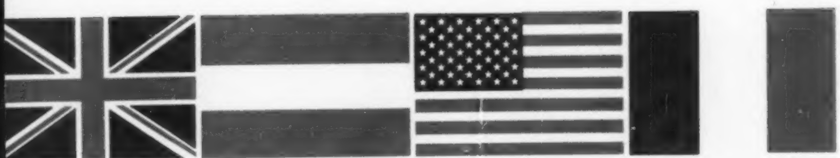
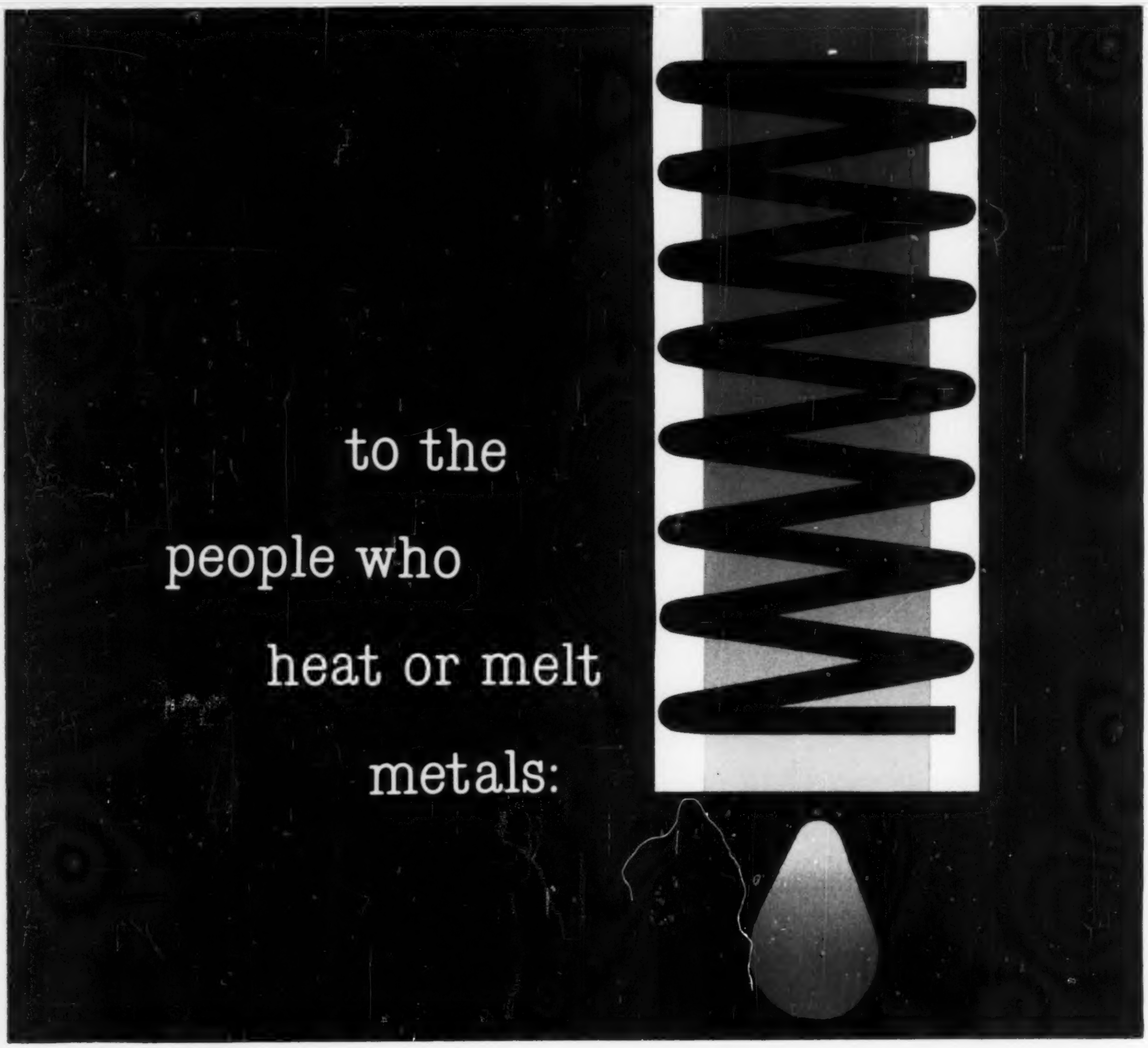


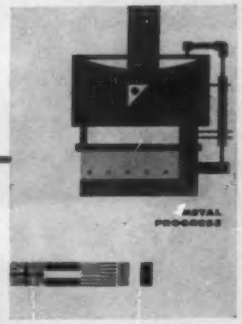
METAL PROGRESS




to the
people who
heat or melt
metals:

Metal Progress

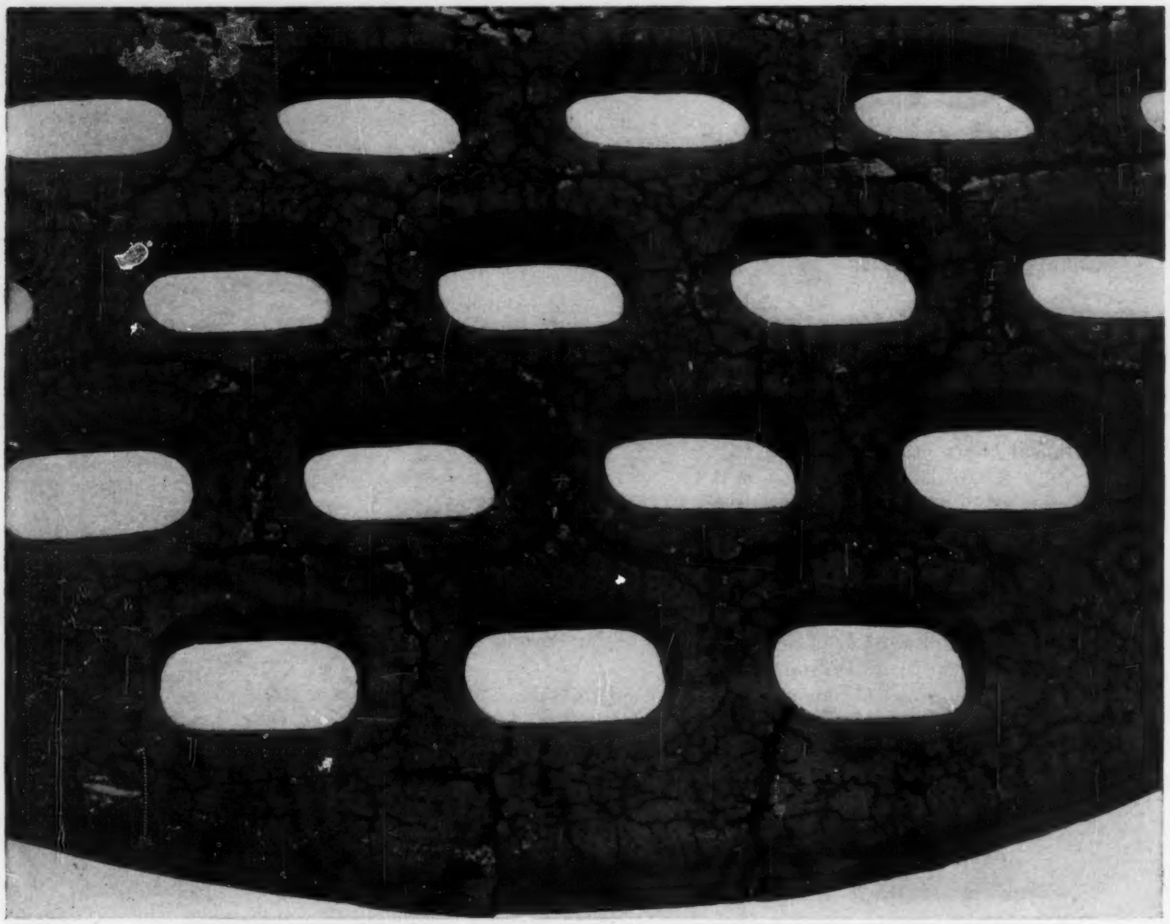
January 1960 . . . Volume 77, No. 1



Cover carries the international theme tied in with an artist's conception of a nice clean teeming ladle. A prizewinner for Phyllis Harvey in the annual competition at Cleveland Institute of Art.

Table of Contents Continued on Page 3

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*



Metal Progress

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New steel degassing technique uses

LITHIUM CAPSULES

Lithium added to the ladle scavenges oxygen and hydrogen from stainless or low alloy steels. Lithium capsules plunged into the ladle vigorously agitate the melt for about 15 to 45 seconds. Degassing is effected with the complete vaporization of the lithium in the melt.

Fast, low-cost lithium degassing increases soundness of billets and improves internal cleanliness. The product of deoxidation (Li_2O) is of low specific gravity and completely self-fluxing. Hence it cannot be trapped in the steel. And the cost of the lithium additions can be as little as 10c per ton of steel.

A Foote sales engineer can give you all the details you need to make your steels cleaner and sounder. Be sure to read our Bulletin 101 *Lithium Metal. For your copy, write Technical Literature Section, Foote Mineral Company, 424 Eighteen West Chelten Building, Philadelphia 44, Pa., or Box 479, Knoxville 1, Tennessee.*

FOOTE
MINERAL COMPANY

PRESS BREAKS

News About the Atom

The other day the Editor-in-Chief was in a friendly discussion with Andy Kramer, editor of *Atomics* (a newsy pamphlet issued by *Power Engineering*), and Jerry Luntz, editor of McGraw-Hill's *Nucleonics*, about which one was first in the field. It appeared to be almost a neck-and-neck race, for *Atomics* was born in September 1945 and *Nucleonics* as a mimeographed document privately circulated in August of the same year. They beat *Metal Progress* by a hair's breadth, for our issue for September 1945 carried President Truman's announcement that an atomic bomb had been dropped on a Japanese city, and in December 1945 we printed a 32-page condensation of the so-called Smyth Report, the official history of the Manhattan Project. Since then we have (in addition to numbers of articles on metals used in atomic reactors) printed very frequently the "Atomic Age" page carrying without comment verbatim extracts from official documents, principally on the political aspects of atomic weapons, the biological effects of radioactive fall-out, or the economics of atomic power – all items admittedly outside the field of metals (materials?) engineering, but matters of transcendent importance to all metallurgists and the metallurgical industries.

The Open Door – As is indicated above, editors do talk. In another such "confab", Editor Merrill of *Plastics* observed that his industry was suffering from an acute case of secrecy and wondered what was the situation in metals, whereupon Editor Thum said that most branches of his industry had discovered that a fence fences out more desirable information than it fences in. While most publicity and advertising men are much more communicative about the high qualities of the stuff they make rather than how they make it, the latter information is usually available to well-qualified members of the engineering press. Without drawing any invidious comparisons, the aluminum industry may be cited. Some 40 years ago, Aluminum Co. of America had a practical monopoly on ingot production; its metallurgists would attend meetings, all ears, but with closed mouths. Later, Alcoa was required to divest itself of its Canadian subsidiary. Then came World War II and to Alcoa's credit it devoted all the necessary talent to the design and building of new plants, and staffed them with members of its own operating organization, even though the plants were actually in the hands of potential competitors. At the present time an editor of a technical or engineering journal can find out as much as he can understand about the refining of bauxite, the potlines, the rolling, extrusion, hot and cold working of aluminum – if not from Alcoa, then from Alcan, Kaiser or Reynolds.

Maybe the plastics industry has yet to grow up.

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Metal Progress

PUBLISHED BY AMERICAN SOCIETY FOR METALS
METALS PARK, NOVELTY, OHIO

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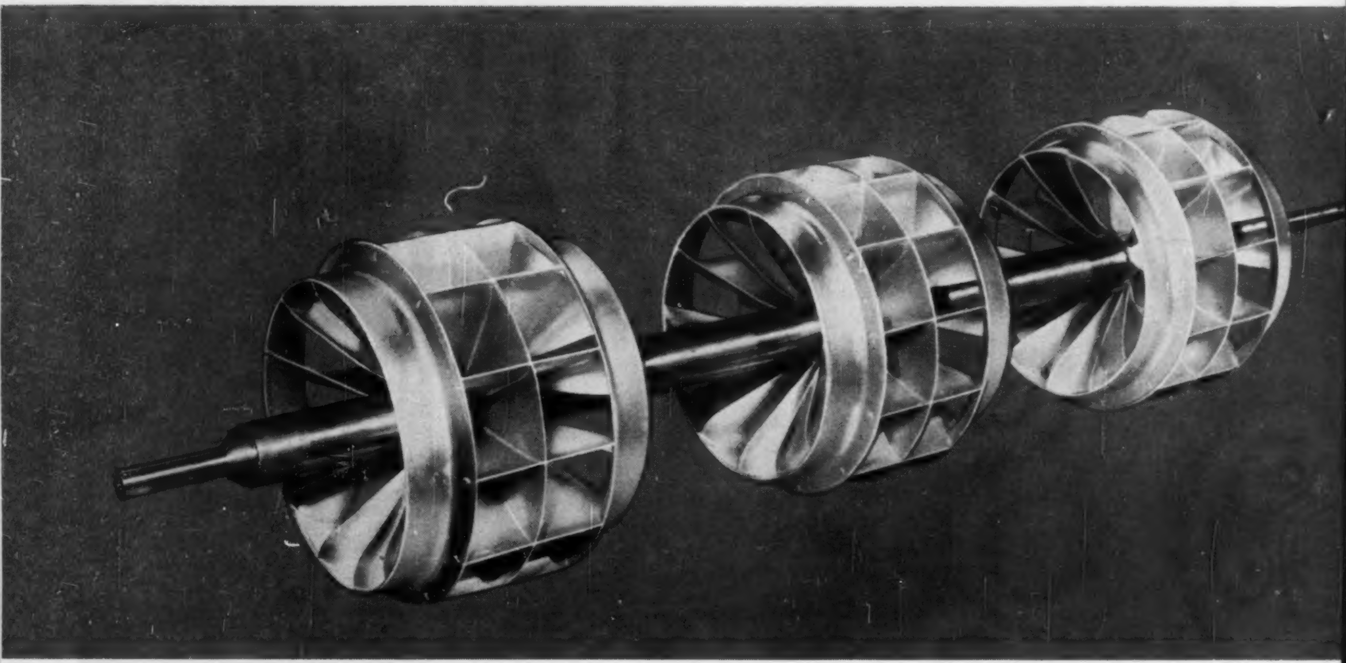
TRULY CONCENTRIC ELECTRUNITE MECHANICAL TUBING ELIMINATES ROTOR SHAFT MACHINING



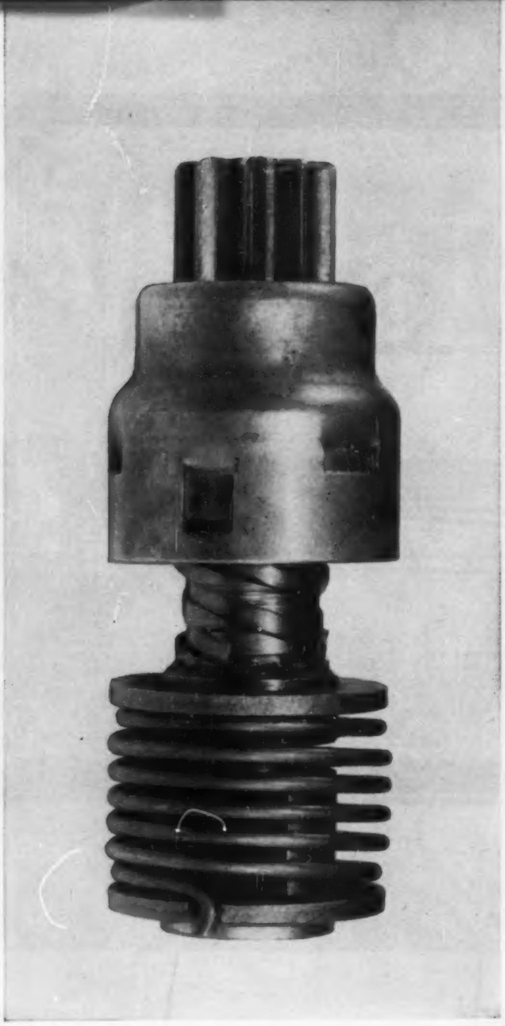
SCROLL-TYPE BLOWERS up to 27″ in diameter are mounted on ELECTRUNITE shafts, some up to 94″ long, and designed to operate at approximately 1,110 rpm. Careful balance and uniformity of the tubing is required for high operating efficiency.

DUE TO THE UNIFORM CONCENTRICITY of Republic ELECTRUNITE Mechanical Tubing, no machining is required in producing air conditioning rotor shafts at Buffalo Forge Company. Rotor shafts are bored at each end and plug inserted for the bearing. Because of the uniformity of ELECTRUNITE, only .015 of the stock is removed before the plug is pressed into the tubing ends.

Buffalo Forge Company, Buffalo, New York, saves valuable machining time by using Republic ELECTRUNITE® Mechanical Tubing in manufacturing air conditioning and ventilating units. ELECTRUNITE in sizes of 3″ to 3¼″ O.D., 8-gage, is used as shafting for the rotors of the blower system.

Scroll-type blowers up to 27″ in diameter are mounted on ELECTRUNITE shafts, some up to 94″ long, and designed to operate at approximately 1,110 rpm. Small shafting will turn at 2,300 rpm. True concentricity of ELECTRUNITE is vital to high operating efficiency of these units due to the careful balance required in relation to the high rpm and weight involved.

Republic ELECTRUNITE Tubing, carbon or stainless, may solve your particular production or cost problems, too. Call your Republic representative, or write direct.



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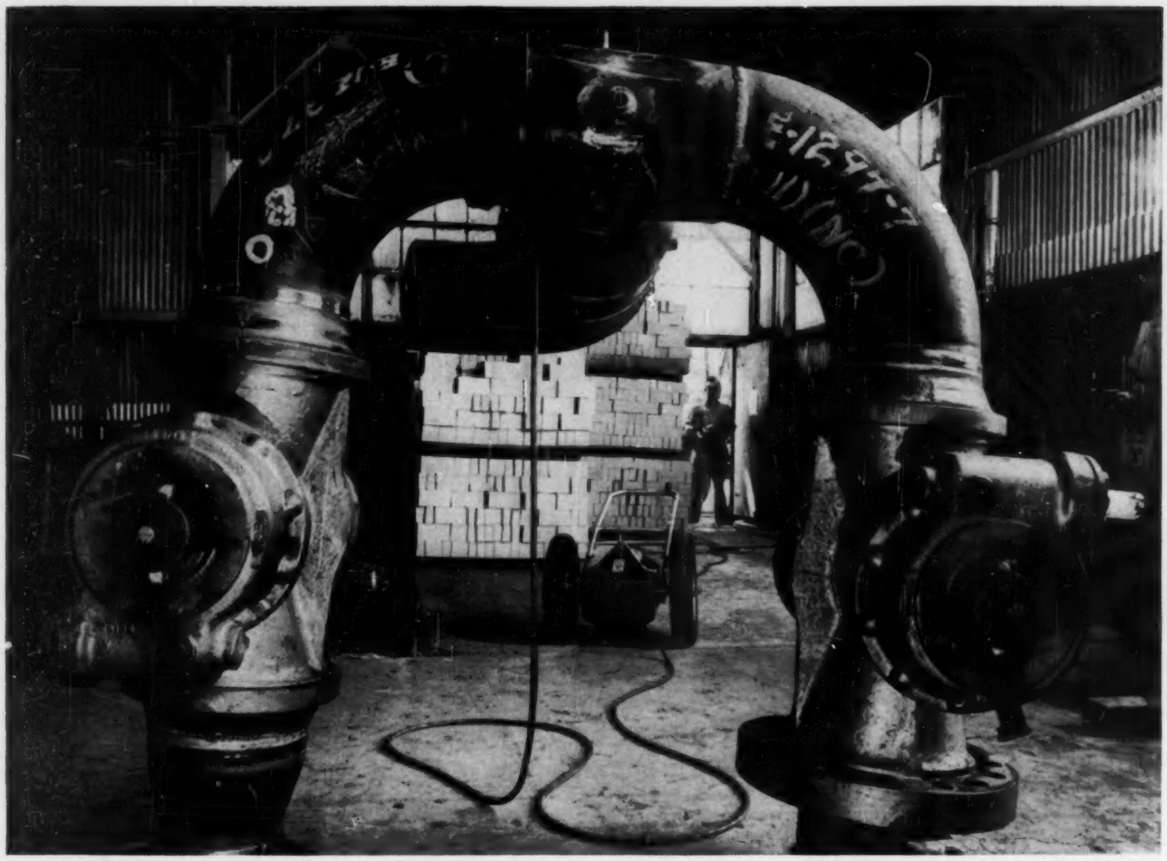

The entire circumference of the left hand weldment at the Tee fitting of this pipe assembly is being radiographed in a single exposure with a Model 50 Multitron. The unit can handle any isotope suitable for gamma radiography . . . and up to four separate sources can be contained in the same machine. A wide variety of exposures can be made—internal, panoramic and beam. Model 50 travels with ease anywhere in plant or field, requires no external power.

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- **Source strengths to 1000 curies**
- **For all exposures—beam, panoramic, internal**

Select the radiography equipment that meets your requirements from the 21 standard Iriditron and Multitron Models now available. One of these models will give you the method or methods of exposure, number of sources, source materials, source strengths, and type of mounting you need. Each model is distinguished by design features that assure you unsurpassed versatility, performance, and safety.

Get complete service from Budd—including radioactive source supply and encapsulation, source replacement and disposal, training for your personnel (without charge) and aid in setting up complete radiographic facilities.

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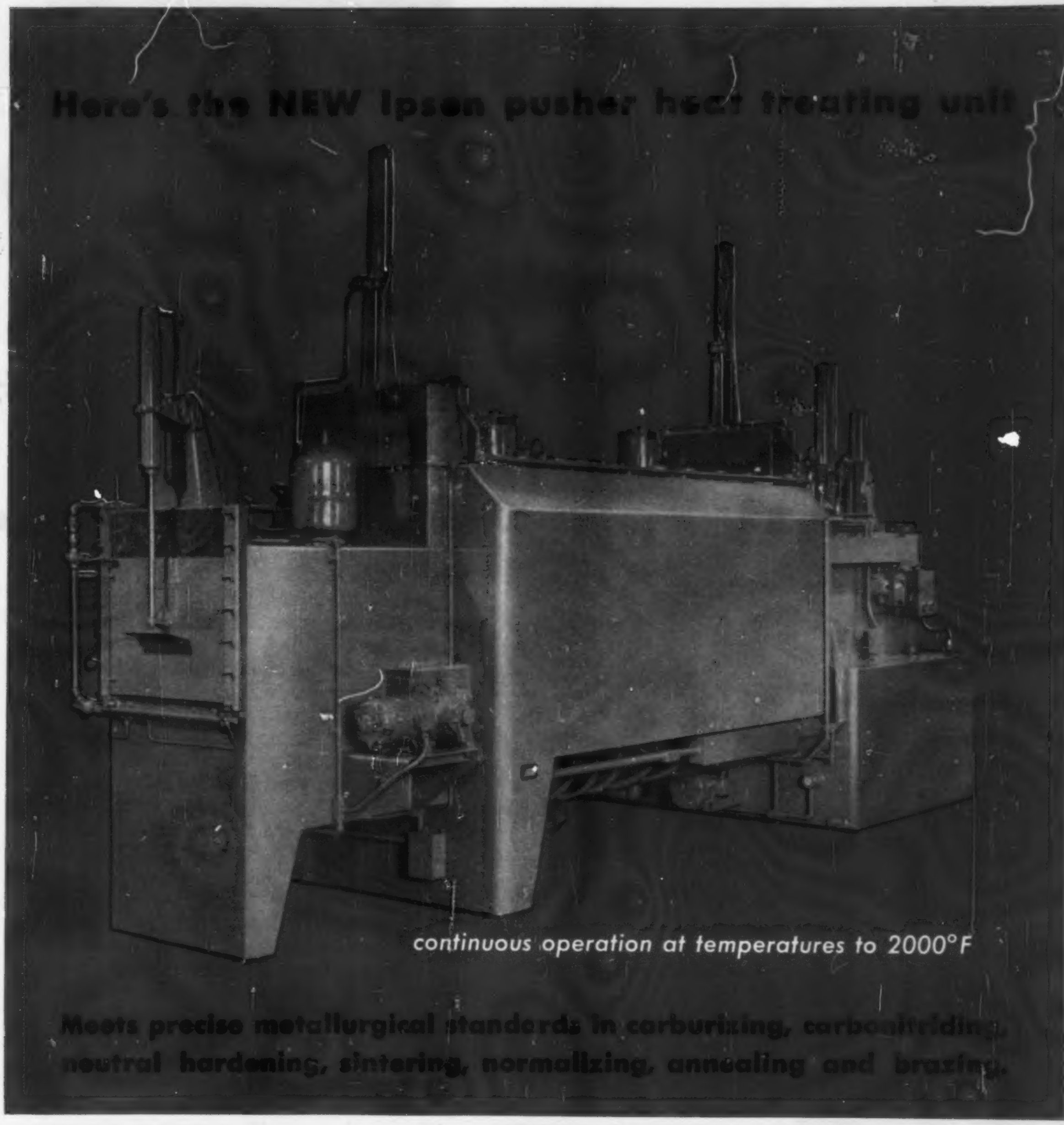
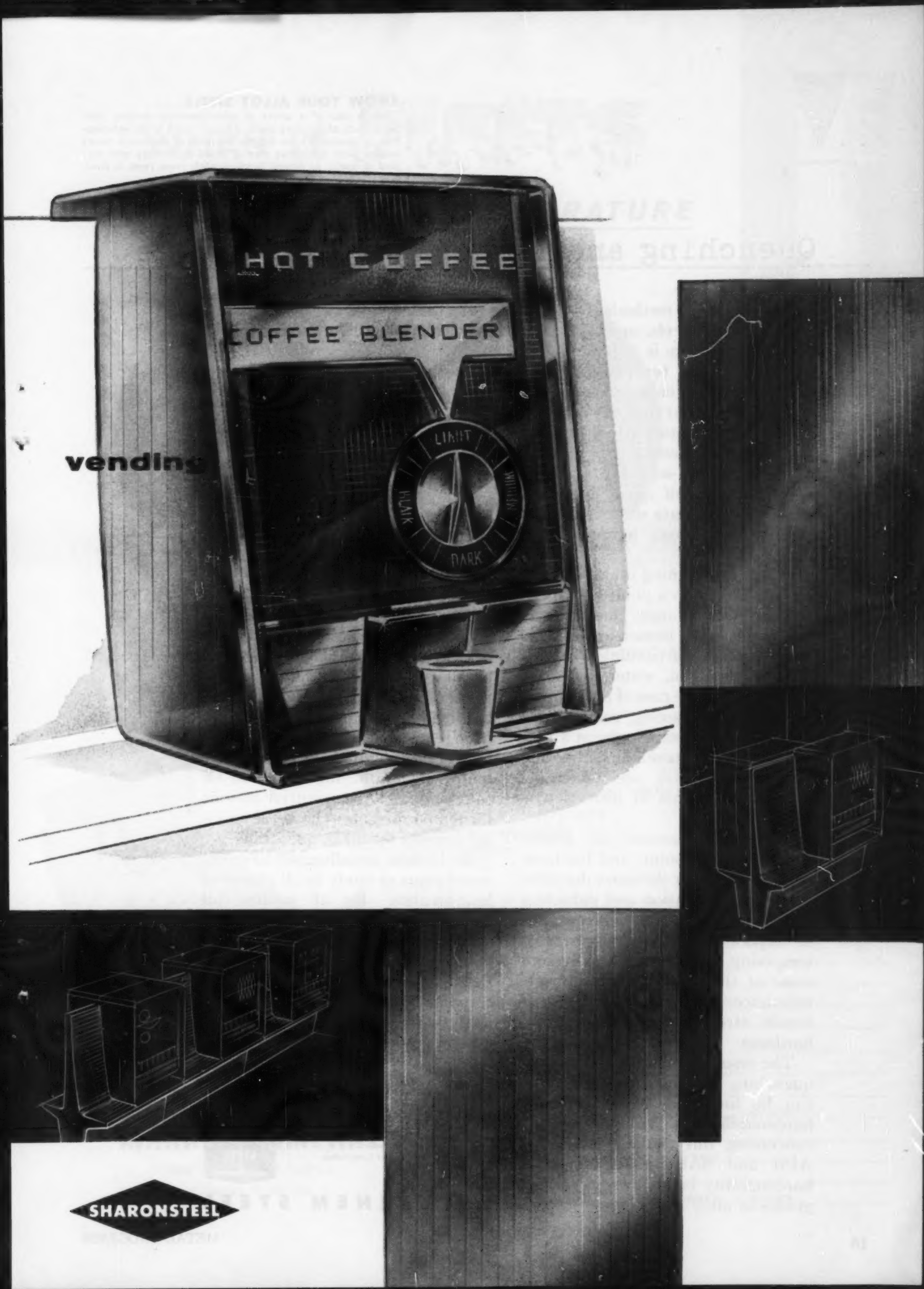


- Each zone with individual 100% forced convection heating!
- Silicon carbide skid-type hearth fully supports light-weight trays.
- Super-alloyed ceramic tubes guaranteed one year. Ipsen "Flame-Busters" complete combustion within the heating portion of the tube.
- Both forced convection atmosphere cooling and hot-oil quench.
- Ipsen pusher units are shipped completely piped, wired, and tested.

Cross-section diagrams and complete details covering all sizes of Ipsen pusher units are shown in Bulletin P-59. Send for your copy, today.

AUTOMATIC **Ipsen** HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 SOUTH MAIN STREET • ROCKFORD, ILLINOIS


HOT COFFEE
COFFEE BLENDER
LIGHT
DARK
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SHARONSTEEL

KNOW YOUR ALLOY STEELS . . .
This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it usefu to review fundamentals from time to time.

Quenching and Tempering Alloy Steels

Of the various methods of heat-treating alloy steels, one of considerable importance is that involving quenching and tempering. This method, which enhances the mechanical properties of the end product, differs materially from normalizing and annealing (previously discussed in this series).

The purpose of quenching is to effect a cooling rate sufficient to develop the desired hardness and structure.

Before quenching takes place, steel is heated to a point above the transformation range. Quenching is the subsequent immersion of this heated steel in a circulated or agitated bath of oil, water, brine, or caustic; or, in the case of austempering or martempering, generally in agitated molten salt baths at a prescribed temperature. Austempering and martempering are preferable where a minimum of distortion is desired.

Quenching *increases* the tensile strength, yield point, and hardness of alloy steels. It *decreases* ductility—that is, elongation and reduction of area. It also decreases resistance to impact. However, by means of tempering, it is possible to restore some of the ductility and impact-resistance—but only at a sacrifice of tensile strength, yield point, and hardness.

The results of mild oil- or water-quenching as related to mass effect can be found in the end-quench hardenability test. Voluminous data concerning this test are issued by AISI and SAE in the form of hardenability bands for the various grades of alloy steels.

If thermal cracking is to be avoided, cooling by liquid quenching should not be carried to a point below 150 deg F. When a temperature of 150 deg F is approached, immediate tempering should follow. Because of residual stresses, no steel should be used in the as-quenched condition.

Tempering can be defined as reheating to a specified temperature below the lower critical range, followed by air cooling. It can be done in furnaces, oil, or salt baths, the temperatures varying from 300 to 1200 deg F. With most grades of alloy steel, it is best to avoid temperatures between 500 and 700 deg because of the "blue brittleness" that occurs in this range. Maximum hardness and wear-resistance result from tempering at low temperatures; maximum toughness is achieved by tempering at the higher levels. Of course, one of the essential reasons for tempering is to relieve the residual stresses set up in quenching.

Bethlehem metallurgists have devoted years of study to all phases of heat-treating. By all means call them if they can be of service to you. And please remember, when you are next in the market for alloy steels, that Bethlehem makes all AISI standard grades, as well as special-analysis steels and the full range of carbon grades.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

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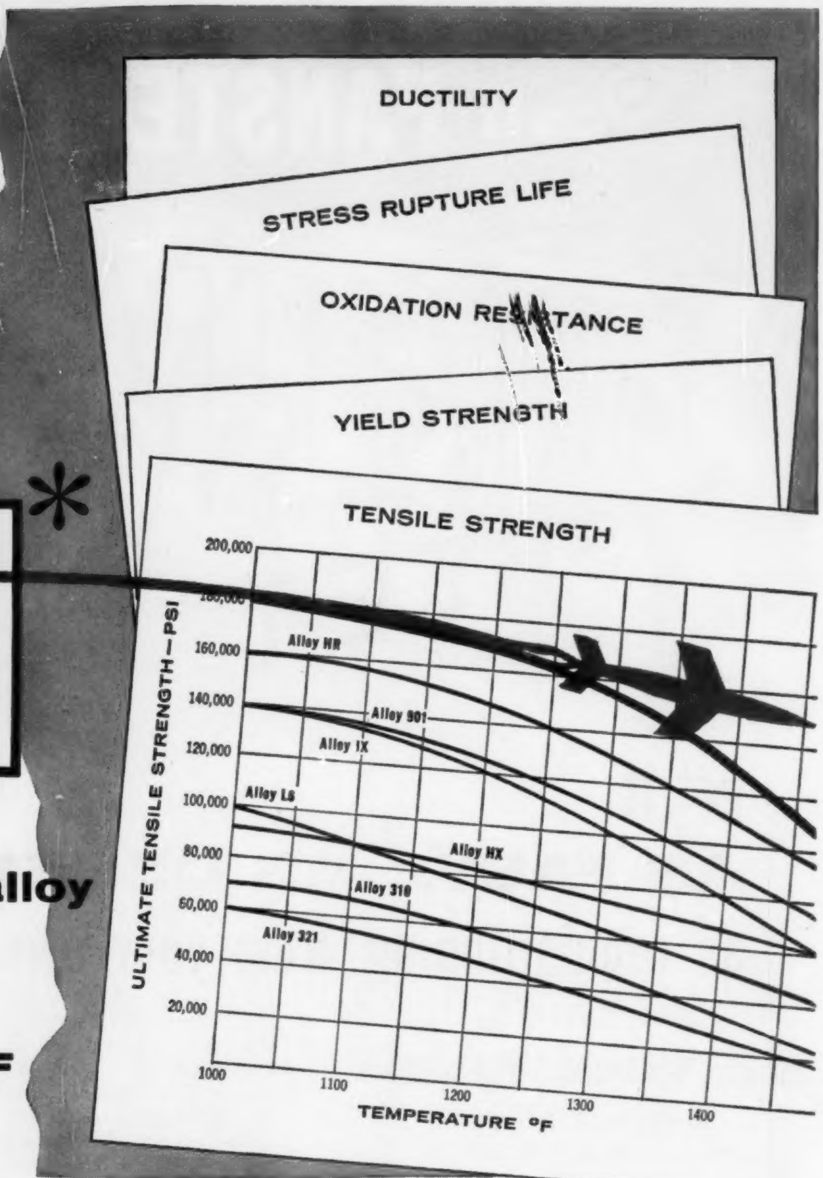
HIGH

on every chart:



RENÉ 41*

most dependable alloy in use today in the 1200°-1800°F range

In *all* ways, René 41 is a remarkable alloy. No other high-temperature alloy used in production today equals its tensile strength. In other properties, too, René 41 is far ahead of the field.

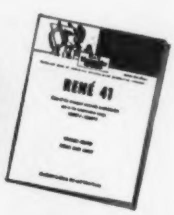
Also important, this nickel-base, vacuum-melted alloy is easy to work with. It's readily formable by drawing, bending, spinning — welds to similar or dissimilar materials.

Cannon-Muskegon offers René 41 in standard 36″x 96″ sheets .015″ to .125″ thick, in smaller sizes down to .010″, in bar stock up to 3″ in diameter . . . foil down to .001 in thickness . . . and fine wire only .0015 in diameter.

For complete details, write for Technical bulletin No. 86.

*TM of General Electric Co.

ULTRAMET
VACUUM ALLOYS



CANNON-MUSKEGON CORPORATION

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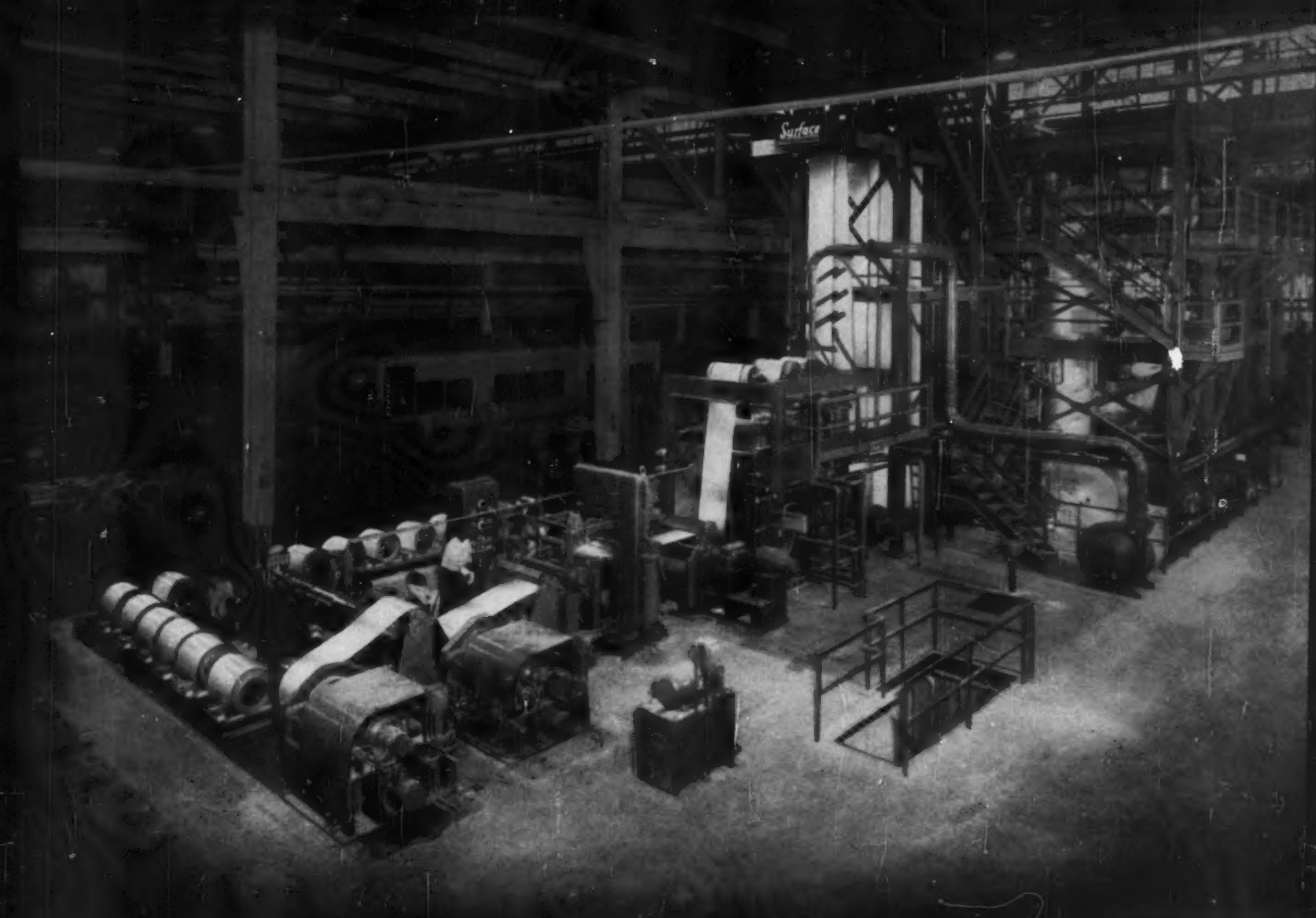
METALLURGICAL SPECIALISTS

1-59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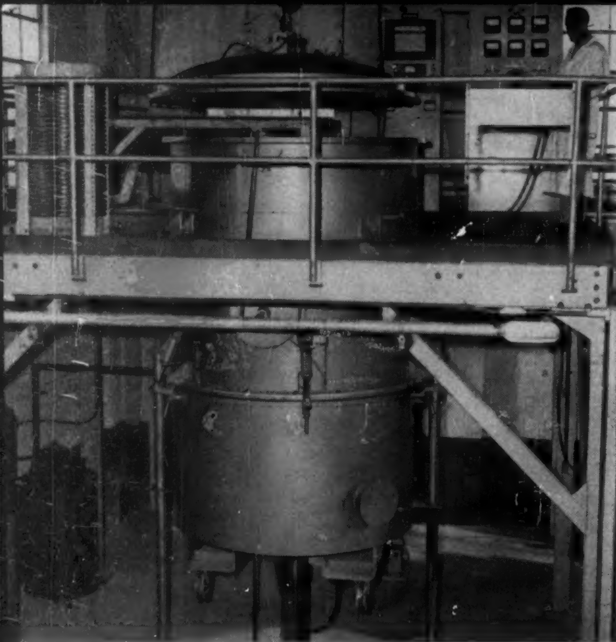


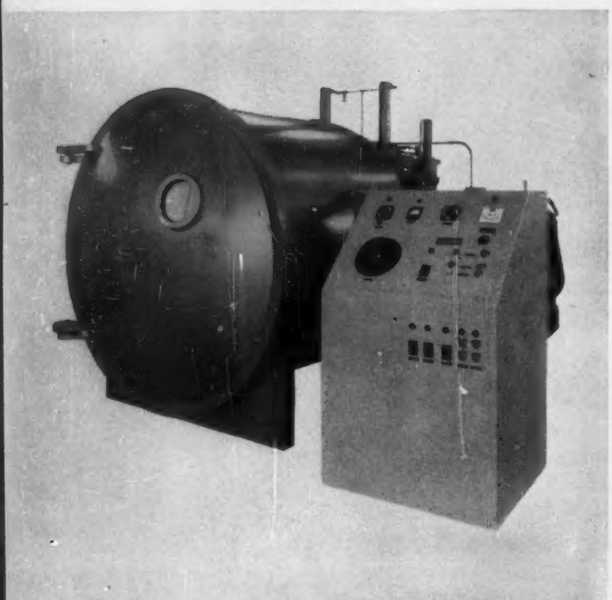
Uranium melting on a production basis is easily accomplished with this Stokes induction melting furnace. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of poured materials. It is typical of the inherent flexibility of Stokes equipment which meets the demands of specific processing techniques and requirements.

Profit from

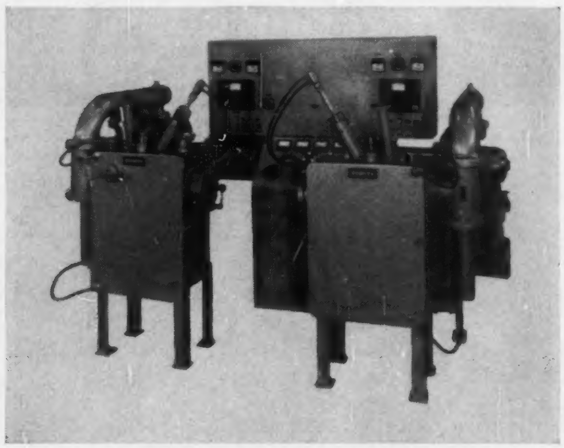
...with STOKES

With a quickening pace, Stokes vacuum metallurgical equipment is helping industry find new paths to profit through a combination of intensified research and practical production techniques.

Stokes design experience coupled with complete manufacturing facilities makes possible meaningful technological developments in vacuum metallurgy. A complete range of types and sizes of furnaces and metallizers are available, and you get a complete



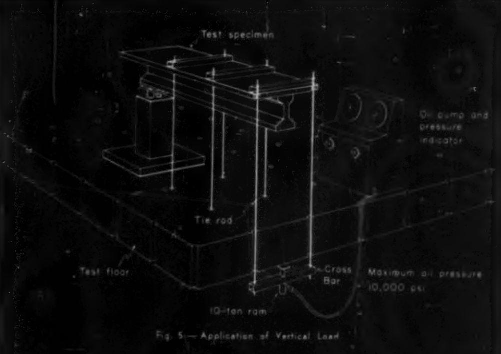
New applications for metallizing are developing at a rapid pace. Vacuum coating with corrosion resistant cadmium and aluminum is playing an increasingly greater role in production of critical, high tensile strength aircraft parts. Lustrous layers of aluminum, vacuum applied on inexpensive metals, can produce quality outdoor lighting reflectors at lower costs. Electronic components, such as resistors, utilize vacuum deposited metallic coatings to achieve weight and space savings with improved reliability, stability and uniformity of temperature coefficient.



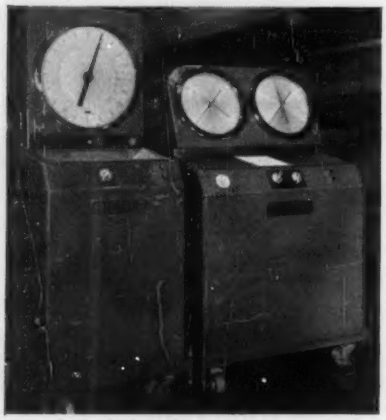
High order investigations in vacuum melting are made possible with this Stokes 50-lb. vacuum furnace. A production unit as well, it is available in single or dual chambers plus a variety of automatic types. The unit is shipped as a completely assembled, ready-to-operate system to save customers time and money.

This laboratory is a giant testing machine in itself

Designed to accommodate a wide range of concrete specimens, from small beams to large structural assemblies, this hydraulic testing machine utilizes the building floor as an integral part. 690 holes in the floor permit versatile arrangements of tie rods which connect load applicator bars to a series of 10-ton rams below floor level.



Custom designed concrete testing machine at Portland Cement Association's Research and Development Laboratories, Skokie, Illinois. Diagram shows hydraulic mechanics.



From below the floor . . . load delivered by RIEHLE units

Mounted on casters, mobile RIEHLE pump and indicator units provide a compact, simple power supply for the rams. A minimum of interconnecting lines and fittings are used to reduce setup time and eliminate major maintenance problems.

Available in capacities from 10,000 to 400,000 pounds, RIEHLE hydraulic units meet your most exacting requirements for either complete standard testing machines or for custom designed equipment.

Available from RIEHLE . . . Hydraulic and Screw Power Universal Testing Machines, Creep, Stress Rupture and Fatigue Testing Machines, Impact, Brinell, Torsion, Construction materials, Horizontal Chain, Rope and Cable Testing Machines, Portable Hardness Testers for Rockwell Readings, Etc.

Riehle® TESTING MACHINES

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American Machine and Metals, Inc.

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"One test is worth a thousand expert opinions" TM

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Dept. MP-160, East Moline, Illinois
Please send free literature on RIEHLE Testing Machines.

(Type of Machine)

NAME

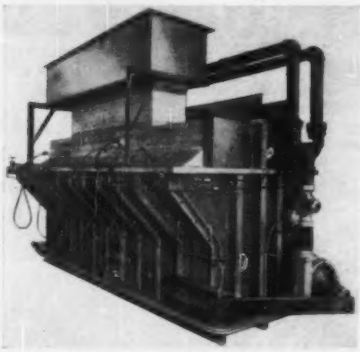
COMPANY

CITY & ZONE STATE

NEW PRODUCTS

Salt Bath Furnaces

New gas or fuel-fired salt bath furnaces have been announced by Ajax Electric Co. Operating to temperatures as high as 2300° F., Ajax-Ankerson furnaces are suited to heating for forging, billet heating, casting and other heavy-duty work involving high tonnage volume in addition to all ordinary salt bath operations. Heating of the salt is accomplished by



radiation to the bath surface in an enclosed chamber. There are no heating elements or alloy pots. Circulation of the bath is obtained by an air-bubbler agitator. With this system, forced air is projected to the bottom of the bath through a series of metal tubes. This circulates the bath and assures no more than 10° F. temperature variation in any part of the bath working area.

For further information circle No. 1 on literature request card, page 48-B.

Nuclear-Quality Tubing

The first two grades of nuclear-quality tubing made to published standards have been announced by Superior Tube Co. Nuclear-quality heat exchanger tubing and nuclear-quality fuel element tubing are furnished in seamless austenitic stainless steels, Types 304, 304L, 316, 347 and 348. Maximum limits are set for the carbon, manganese, phosphorus, sulphur and silicon and for the tantalum content of Type 348 stainless steel. Maximum copper, molybdenum, cobalt and boron are also specified. The finished tubing is 100% inspected for dimensions.

For further information circle No. 2 on literature request card, page 48-B.

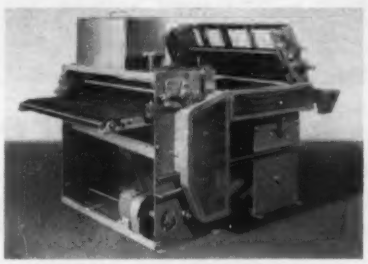
Vacuum Brazing

F. J. Stokes Corp. has announced equipment for production-scale brazing of honeycomb structures under vacuum. The equipment can braze panels over 50 sq. ft. in area. A cylindrical chamber rolls horizontally on twin rails, opens for loading by moving to the left, then closes against a fixed end-plate for evacuation. Heating elements extend across the lower heating tray, all along its length. A duplicate array of heating elements is provided in the upper heating frame which is mounted within the chamber. A tacked-together honeycomb sandwich is placed on a reference base consisting of a block of graphite. A cover sheet is placed over the panel and sealed with an O-ring gasket. A similar cover and gasket below the graphite block completely enclose the panel. During the brazing process, hydraulic cylinders in the top of the chamber force the upper heating frame down onto the cover sheet, compressing the O-ring gaskets and sealing the envelope around the honeycomb panel.

For further information circle No. 3 on literature request card, page 48-B.

Roller Coater

A new roller coater designed for easy cleaning and for use with materials or compounds of high viscos-



ity has been announced by Murray-Way Corp. The upper applicator roll of the roller coater is hinge-mounted so that it may be opened for cleaning. Materials or compounds are applied to the rolls by "ironing" them onto the applicator roll. When extra heavy coatings are required or when a conditioner must be applied to the work before the final coating, roller coaters may be used in tandem.

For further information circle No. 4 on literature request card, page 48-B.

Ultrasonic Gage

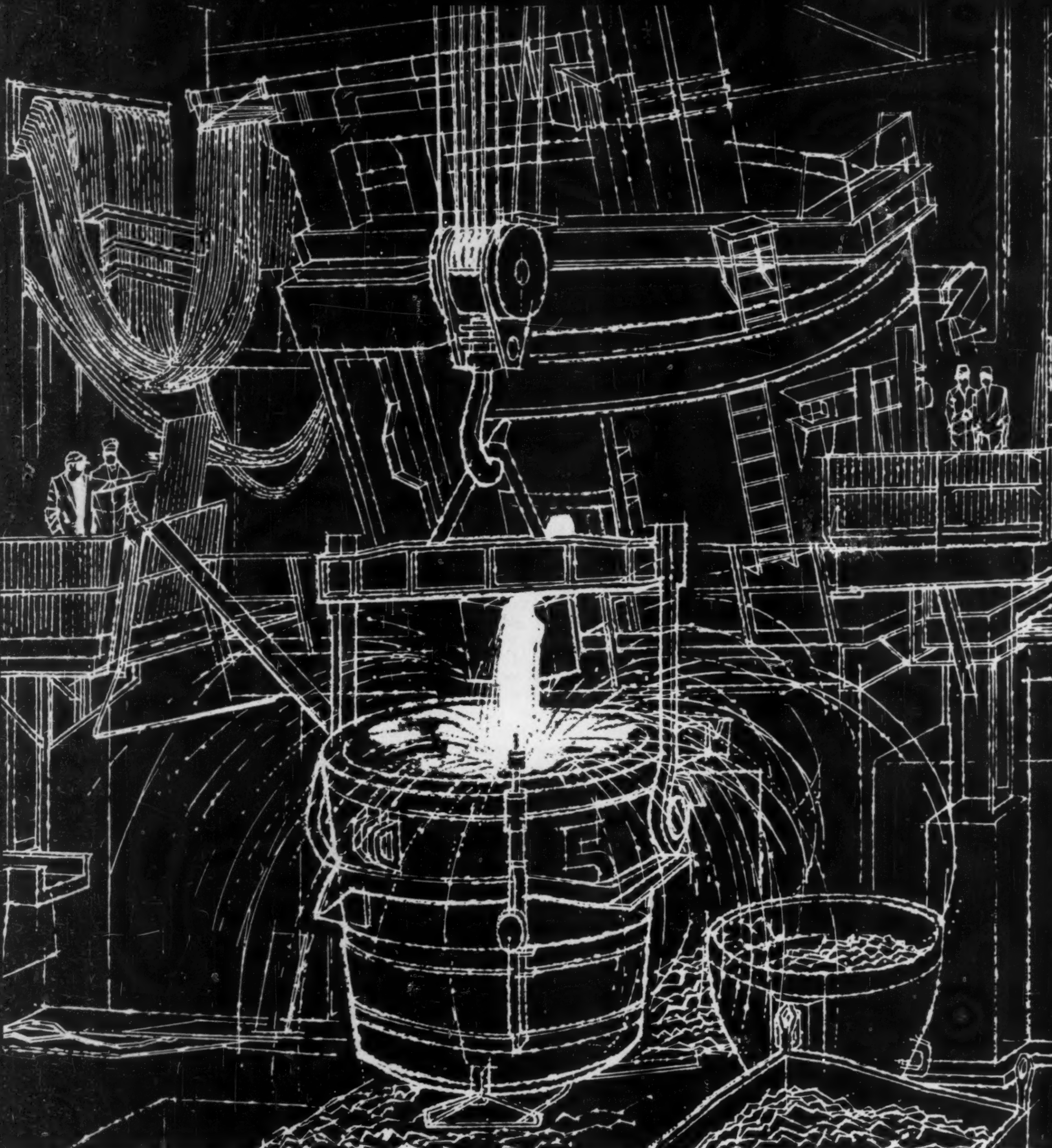
A compact, portable ultrasonic thickness gage that weighs 10 lb. has been announced by Sperry Products, Inc. The new gage will measure thickness and inspect for corrosion in pipe, storage vessels, hull plates and similar applications. Measurements may be read on a directly calibrated meter which eliminates the necessity of interpreting them through an oscillo-

scope and charts. Alarm lamps are provided to set thickness limits. This gage uses the pulse-echo method of detecting changes in metal thickness. It will also detect flaws and other small discontinuities. The pulse-echo type of gage is capable of measuring thickness where the surfaces are not parallel or are pitted or rough because it needs only one reflection of the ultrasonic energy in order to make a measurement.

For further information circle No. 5 on literature request card, page 48-B.

Aluminum Etchant

Pennsalt Chemicals Corp. has announced a new aluminum etchant in solid form. The new solid compound AE-16S produces a durable satin etch on architectural aluminum, is non-

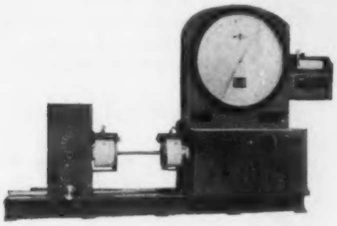


scaling and eliminates sludge. It is used at 2 to 8 oz. per gal. of water at 140 to 170° F.

For further information circle No. 6 on literature request card, page 48-B.

Torsion Testing

A low-capacity torsion testing machine featuring electronic indication of torsional load has been announced by the Tinius Olsen Testing Machine Co. The tester is equipped with a variable speed range from 5 to 180° per min., and speeds can be selected

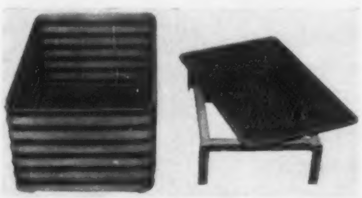


and maintained by a variable-speed electronic motor drive. A 28-in. dial has four load range capacities. This bench-top machine which is available with a capacity of 10,000 in.-lb. will accommodate specimens up to 1 in. in diameter and 24 in. long.

For further information circle No. 7 on literature request card, page 48-B.

Furnace Basket

Corrugated construction to add strength to new parts-holding heat treating baskets has been announced by Wiretex Mfg. Co., Inc. The baskets are made of ⅛-in. Inconel and can



hold 500 lb. of parts. Parts rest on a separator screen of Inconel wire. For jobs in which a two-tier arrangement is desirable, a special rack fits into the basket and supports a second separator screen.

For further information circle No. 8 on literature request card, page 48-B.

Ultrasonics

A new ultrasonic generator that requires no tuning or monitoring has been announced by Industrial Ultrasonics Corp. It operates with an on-off switch and makes use of a fundamental principle of feedback to effect automation. The actual amount of ultrasonic activity in the cleaning tank is measured and used as a basis for varying the output frequency of the generator. The frequency is adjusted automatically until maximum activity (cavitation) is obtained. Load changes resulting from displacement or addition of solvent, heating or cooling or any other cause will not affect the operation of the system.

For further information circle No. 9 on literature request card, page 48-B.

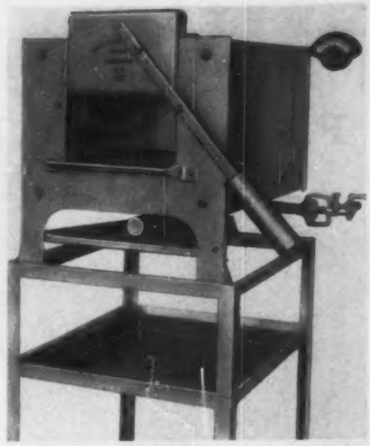
Nickel Coating

Hanson-Van Winkle-Munning Co. has announced a new bright nickel process, Superlume. After original make up, only two addition agents are used. One provides ductility, stress relief and tolerance to impurities. The second addition agent provides high brightness and leveling. Agitation has a beneficial effect. This may be provided by conveyor motion, mechanical agitation, cathode rocker or air agitation. A still bath may also be used.

For further information circle No. 10 on literature request card, page 48-B.

Oven Furnace

Charles A. Hones, Inc., has announced a number of engineering changes in its bench-type oven furnace. A new cast iron venturi burner with modernized port design, and a new hearth mix of a special silicon



carbide formula are two changes. Model No. 55 oven furnaces are available in six standard sizes.

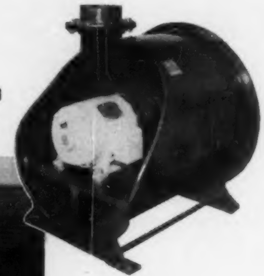
For further information circle No. 11 on literature request card, page 48-B.

Electropolishing

Wm. J. Hacker and Co. has announced a new electrolytic lap-polishing apparatus for metals difficult to polish by usual methods such as tungsten, rhenium, molybdenum and their alloys. Using the Reinacher principle of electromechanical polishing, direct-current voltage is applied to the speci-

RELIABLE SPENCER BLOWERS

FILL MANY NEEDS AT NEW KAISER ALUMINUM PLANT



Ravenswood Works, Kaiser Aluminum & Chemical Corporation, Ravenswood, West Virginia

At this impressive new metal working plant, one of the nation's largest integrated aluminum reduction-rolling operations, *complete dependability* of equipment is an absolute must!

That's why Surface Combustion Corporation selected SPENCER blowers for incorporation on a variety of their heating equipment including:

- Slab Reheat Furnaces
- Annealing Covers
- Soaking Pits

SPENCER BLOWERS WERE SELECTED BECAUSE OF THEIR *PROVEN* ADVANTAGES:

- Anti-surge feature
- Simple construction (hence, minimum maintenance).
- Constant pressure at varying volumes.
- Power savings (air delivered only in proportion to requirements).
- No special foundations, grouting or bolting down necessary.

ALSO MANUFACTURERS OF

PNEUMATIC CONVEYING SYSTEMS

INSTALLED VACUUM SYSTEMS

PORTABLE VACUUM CLEANERS

For complete specifications on Spencer Blowers—from 1/3 to 1,000 H.P., volumes up to 20,000 C.F.M., pressures from 4 oz. to 10 lbs.—request Catalog 126B.

SPENCER

The SPENCER TURBINE COMPANY
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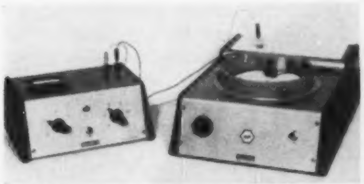
men while slowly abrading it on a polishing wheel covered with abrasive electrolyte slurry. The apparatus consists of polishing disk and a sleeve



with contact to the cathode which are installed on a polishing machine. A special power pack is used to provide the proper electrical current.
For further information circle No. 12 on literature request card, page 48-B.

Graphite Cylinder

A graphite cylinder weighing 7 tons and measuring 61 in. in diameter by 72 in. long has been announced by National Carbon Co. The cylinder will be cored to make sections for a large graphite tower in which elemental phosphorus will be burned for the production of phosphoric acid.
For further information circle No. 13 on literature request card, page 48-B.

Spray Gun

A new spray gun utilizing the plasma-arc principle to develop normal work temperatures of 10,000 to 15,000° F. has been announced by Metallizing Engineering Co. The plasma-flame spray gun will apply coatings of high melting-point materials

such as zirconium carbide (3540° F.), tungsten (3370° F.), tungsten carbide (2850° F.), zirconium boride (3000° F.), zirconium oxide (2700° F.), and niobium carbide (3900° F.). It operates on such inexpensive gases as nitrogen and hydrogen. Coating densities are controlled and approach 98% of theoretical.
For further information circle No. 14 on literature request card, page 48-B.

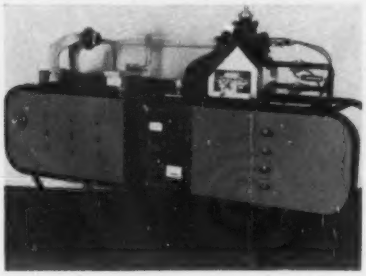
Scale Prevention

A new coating which prevents formation of scale on metal during heat treatment has been announced by the

Los Angeles Div. of North American Aviation, Inc. It may be applied to stainless steel, nickel-chromium alloys, cobalt alloys and copper alloys. Applied by spraying or dipping, the new scale preventive adheres to the metal at furnace temperatures forming an oxygen-tight seal. As the metal cools, the coating pops off.
For further information circle No. 15 on literature request card, page 48-B.

Zone Melting

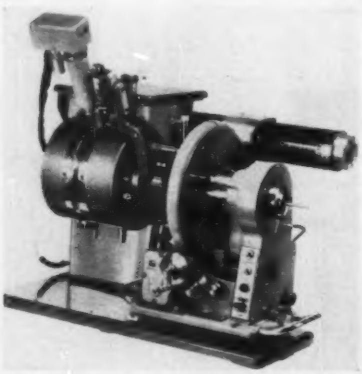
A 1960 model zone-melting apparatus which has an automatic program drive has been introduced by the Materials Research Corp. The drive will turn off automatically after a



preset number of passes, can be set for speeds from 0.10 to 18 in. per hr. and has a quick return of 2 in. per sec. The zone-melting apparatus is equipped with a vacuum system to reach vacuum of 10^{-5} mm. Hg.
For further information circle No. 16 on literature request card, page 48-B.

Spectrograph

A new vacuum X-ray spectrograph has been announced by the Instruments Div., Philips Electronics, Inc. Used in conjunction with the standard basic X-ray generator, the unit consists of a base plate and column,



specimen chamber with tube mount, specimen holder disk, four multi-purpose specimen holders, motor for specimen rotation, collimating system, crystal chamber with crystal changer, and flow proportional counter. The entire X-ray path can be evacuated. The vacuum required is of the order of 0.5 mm. Hg. Four specimens can be simultaneously inserted into the specimen chamber thus reducing the time to re-establish the vacuum to approximately 15 sec. per sample.
For further information circle No. 17 on literature request card, page 48-B.

High-Purity Aluminum

Aluminum of 99.992% purity has been announced by Aluminum Foils, Inc. The high-purity aluminum is available in the form of pigs of various sizes, ingots, billets, pellets, coiled sheet and foil. An electrolytic refining process developed in Europe is used to produce aluminum in this high-purity commercial form. Good finish and high corrosion resistance are outstanding properties.
For further information circle No. 18 on literature request card, page 48-B.

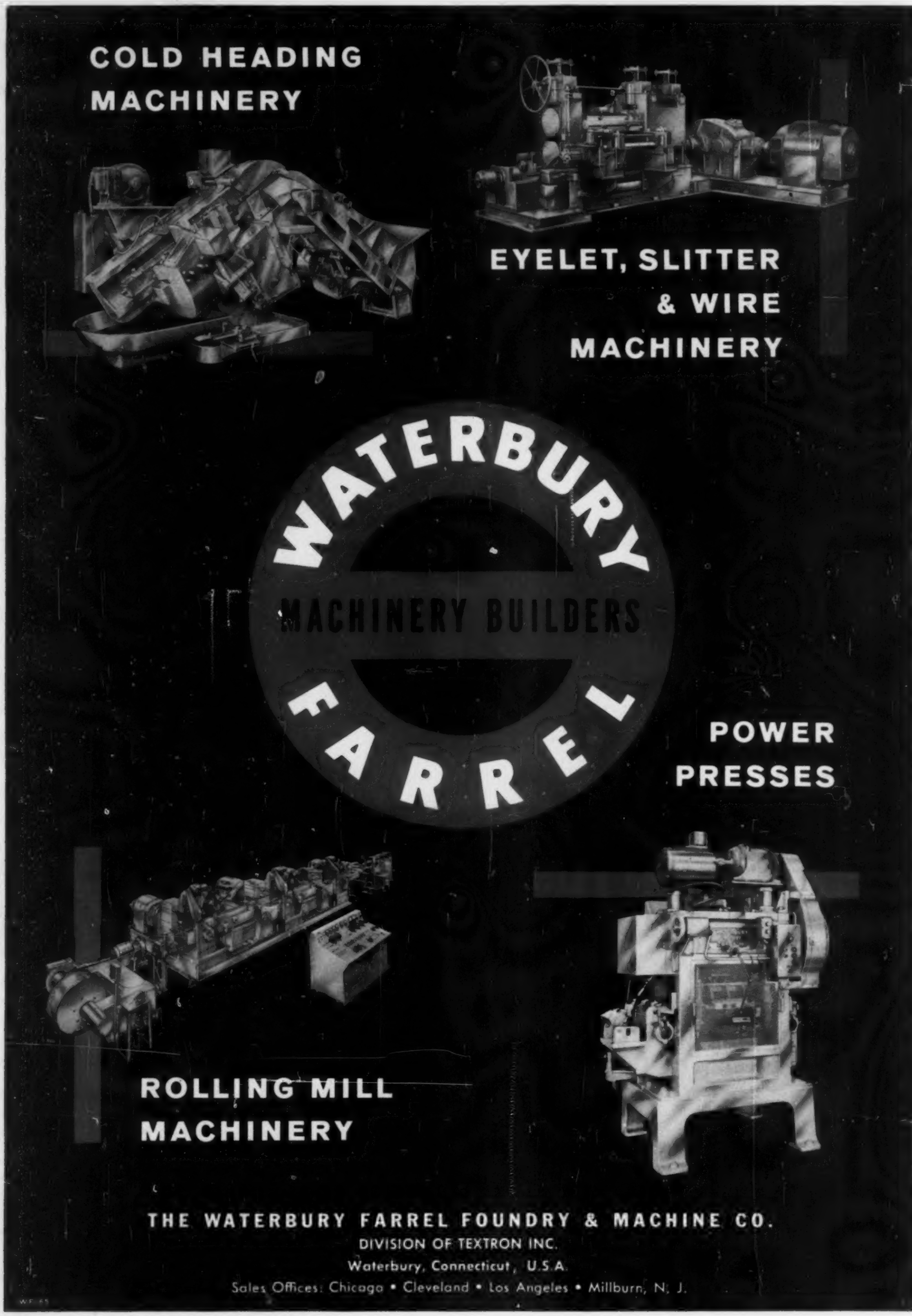
Portable Induction Heater

A new remote-operated induction heater has been announced by Induction Heating Corp. The new portable unit makes it possible to bring the

work coils to the work when the workpieces are large, cumbersome, unwieldy or immovable. The induction unit and its accessory equipment are mounted on a mobile platform. The unit comes with dual output station and required controls for accessory equipment and each remote station. Two coaxial cables furnish power to two work coils in different parts of the plane.
For further information circle No. 19 on literature request card, page 48-B.

Temperature Control

A new differential-expansion type controller for operation at temperatures up to 2000° F. has been announced by Burling Instrument Co. Essentially a temperature transmitter, it provides air pressure proportional to temperature and is used for direct operation of air-operated diaphragm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valves, motors, dampers or similar equipment. Installation is made by inserting the tube assembly in a

heated space by means of one of several types of mountings. Air connections are made to fittings shown at the top. Temperature setting is made with external knob.

For further information circle No. 20 on literature request card, page 48-B.

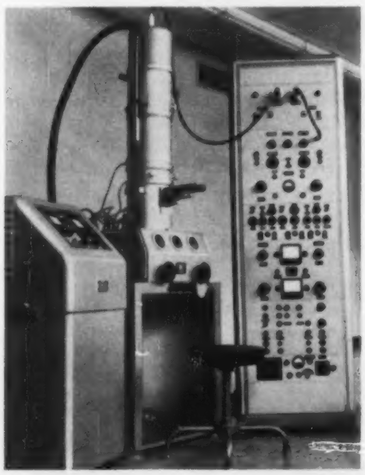
Graphite

Graphite pieces 35 ft. long by 12⅛ in. square have been announced by the Electrode Div., Great Lakes Carbon Corp. They were developed for molds. Special equipment and handling devices were needed to process graphite shapes of this length.

For further information circle No. 21 on literature request card, page 48-B.

Machining

A new electron beam machining process has been announced by L. R. Industries, Inc. Holes and figures can be cut into tungsten, diamond, carboloy, steel, brass, and aluminum, to widths as small as 40 microns across,

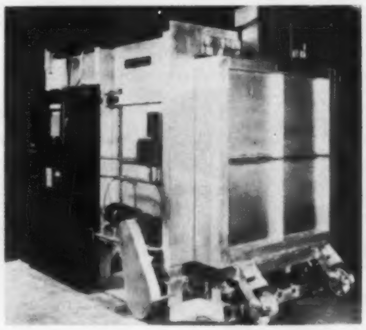


and with tolerances of ±5 microns. Dimensions are programmed electronically in the machine doing the electron-beam machining. The work is accomplished by means of a beam of electrons which because of their high energy density volatilize the material at the focus of the beam. Undesirable effects in the adjacent areas are minimized by pulsing the beam on and off with short dwell times.

For further information circle No. 22 on literature request card, page 48-B.

Furnace

Self-contained car-bottom furnaces have been announced by the Waltz Furnace Co. The furnace shown is 3 ft. wide, 3 ft. high, and 6 ft. long. The car is motor driven by a rack and pinion gear. Additional wheels pick it up as it runs inside the furnace. The heating elements mounted on side walls, the back wall, the door, and



the car draw a maximum of 100 kw. and connect to a 440 v., 3-phase, 60-cycle contactor.

For further information circle No. 23 on literature request card, page 48-B.

Phosphate Coating

A new dry phosphatizing process that eliminates water solutions in applying protective phosphate coatings to metal parts has been announced by the DuPont Electrochemicals Dept. In the new process, metal parts are given a phosphate coating by dipping or spraying with a trichlorethylene-base phosphatizing solution maintained at its boiling point (188° F.). As the parts emerge from the trichlorethylene vapor zone, the solvent completely evaporates leaving parts dry and ready for painting.

For further information circle No. 24 on literature request card, page 48-B.

Stainless Steel Powder

A new flowable stainless steel powder mix for producing corrosion-resistant machine components and equipment has been announced by Union Carbide Metals Co. The new product is not prealloyed. With the established techniques of powder metallurgy, this stainless steel powder can be used to produce structural shapes which exceed 95% of theoretical den-

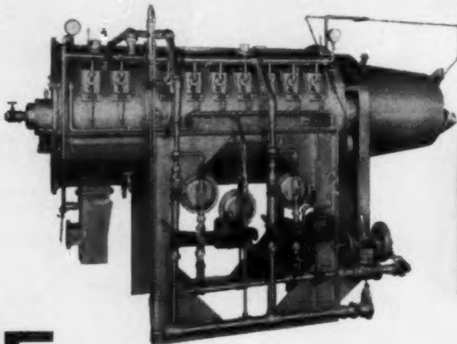
choose the versatile Best...

AGF

AMERICAN GAS FURNACE CO.
81 YEARS OF PIONEERING
1878 1959
ELIZABETH, N. J.

ROTARY RETORT AND RECIPROCATING HEARTH

for all small parts heat treating



AGF

Model [illegible]

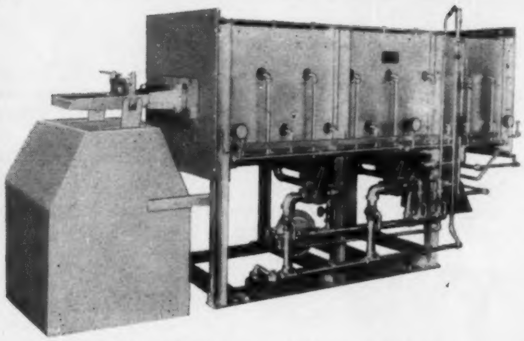
Medium size rotary furnace for the most economical heat treating of parts that can be subjected to a gentle tumbling (approximately ½ r.p.m.).

Tumbling insures uniform heating and atmosphere contact.

AGF

Model [illegible]

Medium size Shaker Hearth Furnace for the widest range of work, even light and delicate stampings. Momentum imparted to each work piece conveys it individually through the heat with no distortion or warpage.



Capacities to 800 lbs. per hour. Processing pieces from .010″ to 1″ thickness and up to 10″ in length. Automatic continuous feeding reduces direct labor costs drastically! Clean hardening, ammonia-gas case hardening, light case carburizing of steel parts, etc., are accomplished equally well WITHOUT ANY MODIFICATION OF THE FURNACE.

The muffles and retorts are, in reality, radiant tubes WITHIN which the work and atmosphere gas is contained. Zoned combustion systems uniformly heat these muffle tubes from the outside to the desired temperature in each work zone. Control is precise, results uniform.

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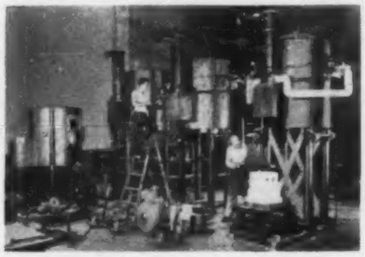
sity. The composition of the powder is similar to Type 316 or CF-Mo alloys.

For further information circle No. 25 on literature request card, page 48-B.

Furnaces

The Electric Furnace Div. of Harrop Ceramic Service Co. has announced elevator-type gas-fired furnaces for research and production. Each unit

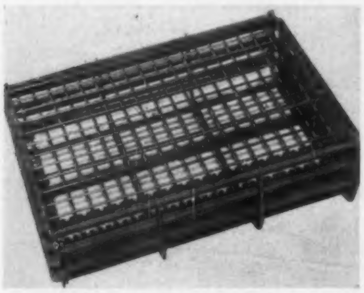


installation has a separate instrument cabinet. Furnaces use natural or petroleum gas with a single control valve on the gas line and operate at up to 3300° F. Furnaces are available in 12, 18, 24 and 36-in. diameters.

For further information circle No. 26 on literature request card, page 48-B.

Furnace Fixture

Bix Co. has announced a heat treat fixture which is not welded and has an adjustable opening. It was designed to hold parts of varying diame-

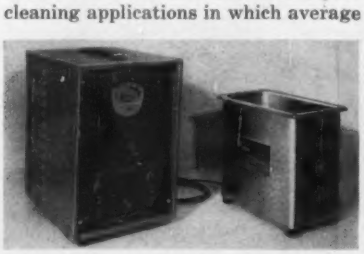


ter, individually suspended. By adding or removing rods, the opening can be made larger or smaller and by raising and lowering the rods, varying tray heights can be made.

For further information circle No. 27 on literature request card, page 48-B.

Ultrasonic Cleaning

National Ultrasonic Corp. has announced a new unit for small part cleaning applications in which average



energy levels are required. The cleaner features a 1-gal. tank 9¼ in. long by 5 in. wide by 6 in. deep. Driving elements cover 25% of the bottom of the tank and actual radiating surface is 12 sq. in. The generator operates on 115-v. a.c., single-phase, 60-cycle current and is designed for continuous operation.

For further information circle No. 28 on literature request card, page 48-B.

Vacuum Pumping

Portable high-vacuum systems for shop or laboratory have been announced by NRC Equipment Corp. Connection to a source of cooling water and to a 220 or 440-v. electrical supply makes them operable. They can also be used as supplementary pumping systems when faster pumpdown or greater capacity is required. Models are offered with 2, 4 and 6-in. diffusion pumps.

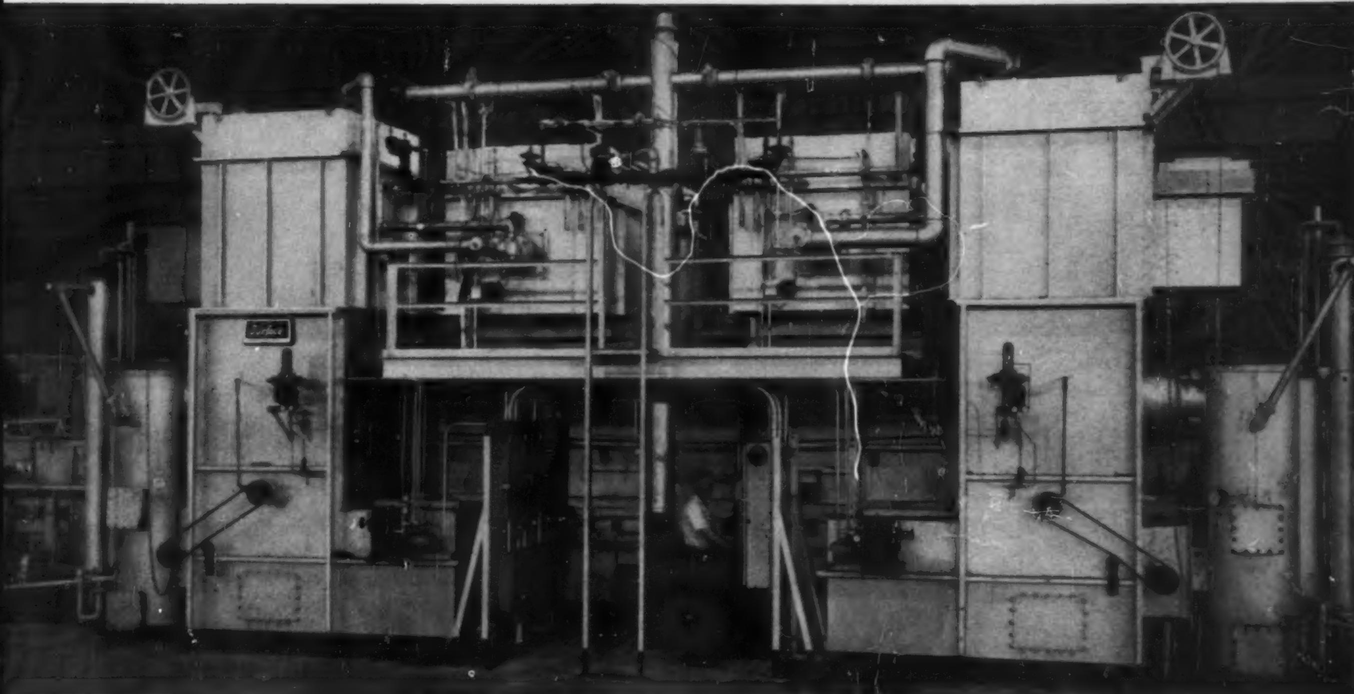
For further information circle No. 29 on literature request card, page 48-B.

Automatic Welding

Air Reduction Sales Co. has announced two new automatic units for use with its tungsten inert-gas welding process. The units are electronically controlled and can be used for either a.c. or d.c. welding without

an accessory control, using argon, helium or mixtures of these shielding gases as required. The units have touch or high-frequency starts, 360° rotation in any position with a 2-in. adjustment of the machine holder across the weld bead, and vertical travel distance of 14½ in.

For further information circle No. 30 on literature request card, page 48-B.



SURFACE POWER CONVECTION

speeds annealing rate to 8,000 lbs/hr of brass tubing

This furnace is one of Scovill Manufacturing Company's (Waterbury, Connecticut) answers to the threat of imported brass and copper mill products.

Scovill is after new highs in production and quality in its new streamlined tube mill at New Milford, Conn. This continuous roller hearth furnace, equipped with Surface Power Convection, helps achieve both goals. It anneals and cools 8,000 lbs. of brass and cupro-nickel tubing an hour. At the same time, it produces tubing of superior physical properties because it maintains temperature uniformity at plus-minus 8° F.

Such process speeds and temperature uniformity are possible only with Surface Power Convection, the most important advance in convection heat transfer in 20 years. Ask your Surface representative how you can apply this profitable new technology to your products. Write for Bulletin SC-182.

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In Canada: Surface Industrial Furnaces, Ltd., Toronto, Ontario

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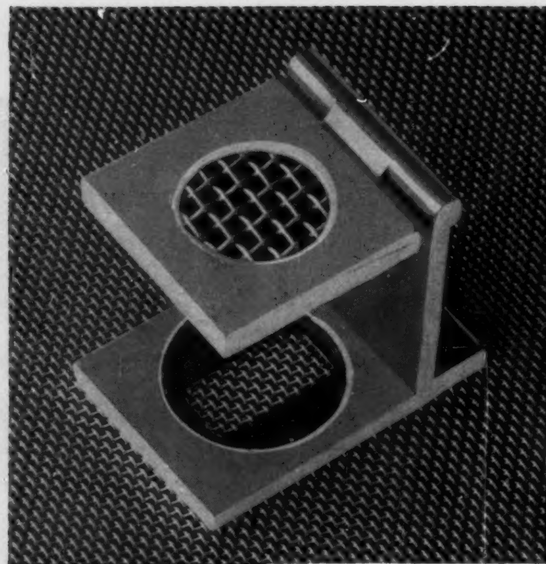
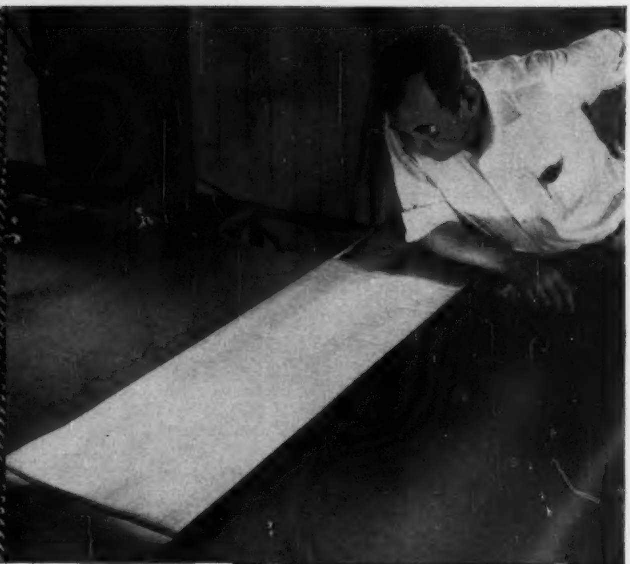
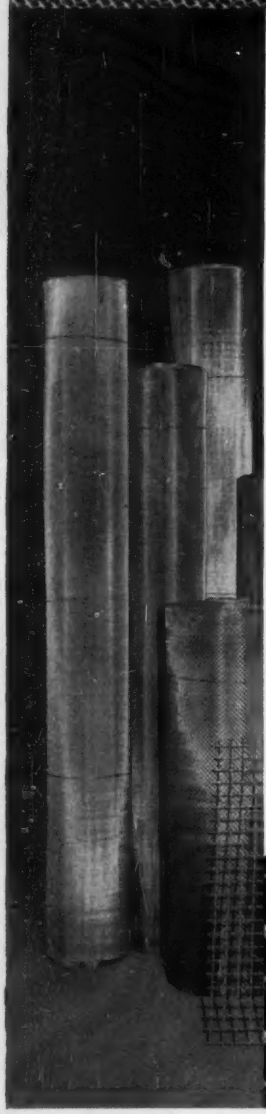
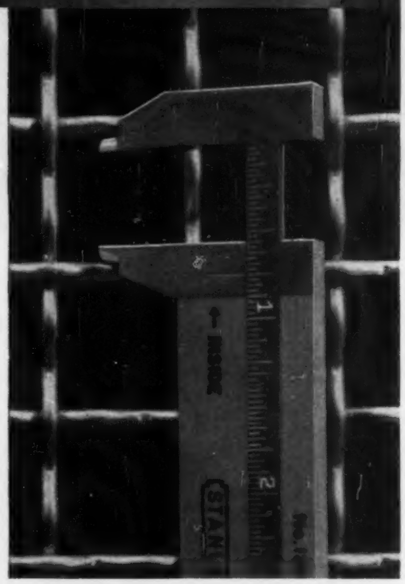
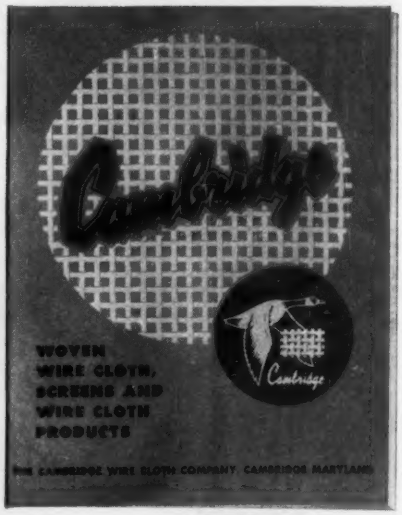
wherever heat is used in industry





Cambridge
WOVEN WIRE CLOTH, SCREENS AND WIRE CLOTH PRODUCTS
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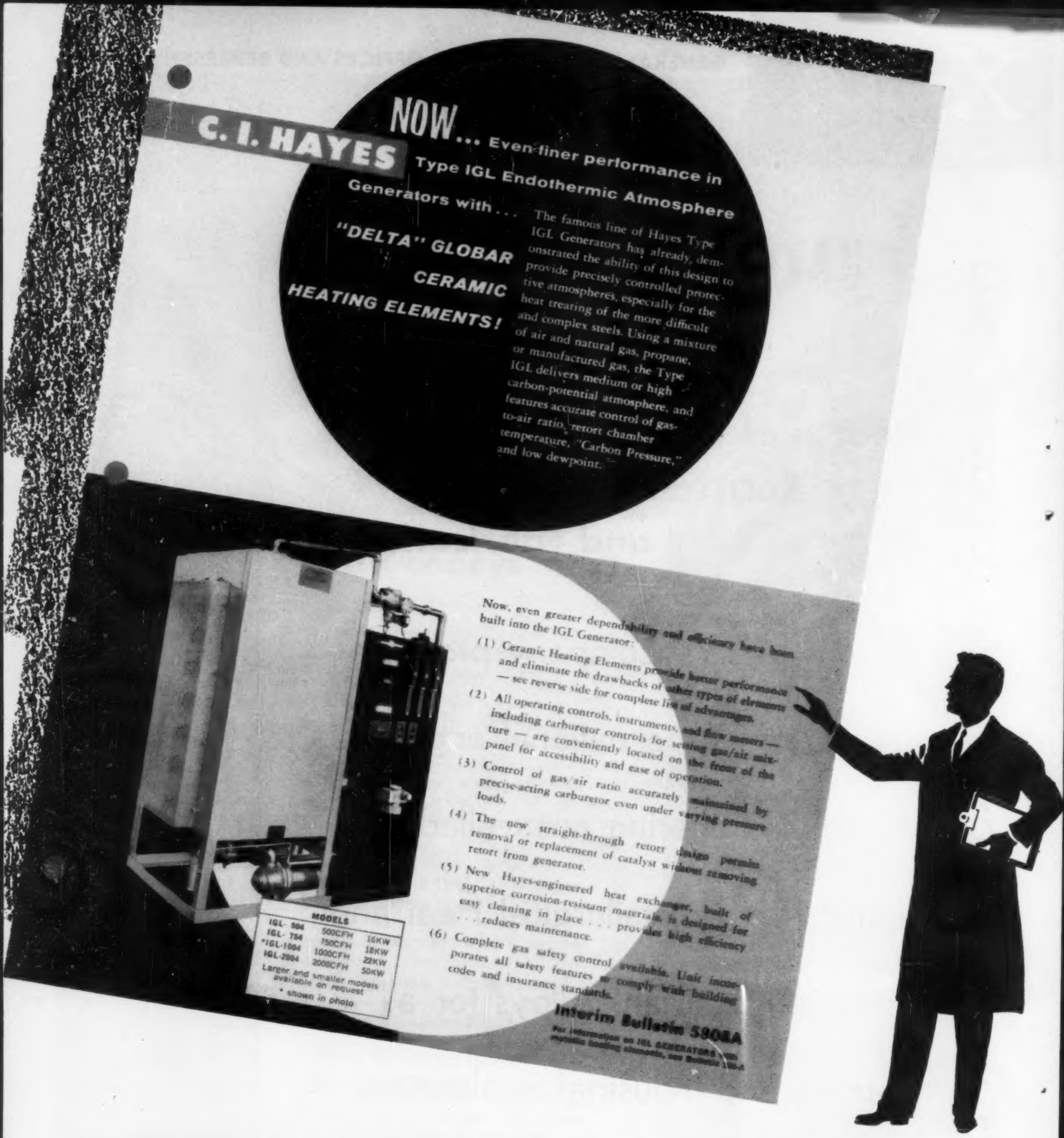

This improved endothermic generator has been on the line over 9000 hours (actual case . . . name of installation on request) without change of Globar elements or retort . . . requiring only 2 to 3 hours downtime for catalyst change (after thousands of hours of catalyst life).

Bulletin 5808A gives the facts. Write C. I. Hayes, Inc., 802 Wellington Ave., Cranston 10, R. I.

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ESTABLISHED 1905

NEW LITERATURE

41. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it can be used with and parts that can be cleaned. *Globe Steel Abrasive*

42. Abrasives
Catalog of rubberized abrasives, uses, advantages. Price list. *Cratex Mfg. Co.*

43. Alloy Steel
68-page "Aircraft Steels" includes revised military specifications. Also stock list. *Ryerson*

44. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

45. Alloy Tubing
New bulletin on tubing and pipe made of Hastelloy B and C. Corrosion resistance, high-temperature properties. *Carpenter Steel Co.*

46. Aluminum Bronze Alloys
20-page booklet on chemistry, physical properties and uses of aluminum bronze alloys in rolled, extruded and cast form. *Ampco*

47. Aluminum Casting Alloys
8-page bulletin on aluminum casting alloys. Properties; selection of casting method: pig, ingot and billet compositions. *Metals Div., Olin Mathieson*

48. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

49. Aluminum Extrusions
Catalog of extrusion dies in stock. *Jarl Extrusions*

50. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions*

51. Analysis of Nickel Alloys
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys". *International Nickel*

52. Analytical Balances
12-page catalog gives features, ordering information, accessories, maintenance of seven types of balance. *Burrell Corp.*

53. Analytical Equipment
18-page brochure on X-ray diffraction and spectroscopy equipment, cameras and camera accessories. *RCA*

54. Analytical Instruments
New 8-page brochure on line of spectrographs, spectrometers, comparators and special instruments. *Jarrell-Ash Co.*

55. Atmosphere Analyzer
4-page bulletin on furnace atmosphere analyzer. Flow system diagrammed. *Perkin-Elmer Corp.*

56. Atmosphere Control
8-page Bulletin SC-178 on furnaces, atmosphere equipment, controls for various heat treating processes. *Surface Combustion*

57. Atmosphere Furnace
Bulletin HD-1 on batch-type controlled atmosphere furnace. Specifications, atmosphere circulation. *Dow Furnace Co.*

58. Atmospheres
8-page bulletin on heat treating. Data sheets on processes and processing equipment. Also covers annealing, brazing and hardening. *Ferrotherm*

59. Austempering
Bulletin No. 167 on mechanized salt bath installation for continuous heat treatment of farm tools. *Ajax Electric*

60. Barrel Finishing
36-page booklet on complete line of abrasive mediums, compounds, and equipment for all tumbling operations. *Electro Minerals Div., Carborundum Co.*

61. Beryllium Oxide
New 8-page brochure on properties, fabrication and products of beryllium oxide. *Beryllium Corp.*

62. Blackening Process
4-page brochure on new activated material for black-oxide processing. *Mitchell-Bradford Chemical Co.*

63. Blast Cleaning Barrels
New 16-page bulletin on standard-duty blast cleaning barrels. *Pangborn Corp.*

64. Bolts
16-page booklet on high-strength bolting for structural joints includes ASTM specifications covering this bolting material. *Bethlehem Steel*

65. Brazing
16-page pocket-sized guide to selective fluxing for low-temperature silver brazing. *American Platinum*

66. Brazing
52-page Publication GEA-3193C on how and where to use electric furnace brazing. Limiting creep of brazing metal, selecting the brazing metal, strength of furnace-brazed parts, how to braze cast iron, causes of distortion. *General Electric*

67. Brazing Alloys
4-page bulletin on high-purity alloys for brazing low-vapor-pressure vacuum tubes. Brazing-temperature and composition charts. *Handy & Harman*

68. Brazing Alloys
Data on brazing stainless alloys. *Wall Colmonoy*

69. Carbides
22-page catalog on tungsten, titanium, columbium and tantalum carbides. Physical and mechanical properties. Applications. *Kennametal*

70. Carbon Control
16-page bulletin on equipment for carbon and sulphur determination, including combustion furnaces and other accessories. *Harry W. Dietert*

71. Carbon Control
Bulletin C-22 and reprint on Carbontronik for automatic control of carbon potential of atmospheres. *Ipsen*

72. Casting
New 8-page brochure on bimetallic casting. Applications, design data. *Arthur Tickle Engineering Works*

73. Ceramics
4-page folder lists industrial products and bulletins describing them. *McDanel Refractory Porcelain Co.*

74. Chemical Cleaning
18-page file-type bulletin No. 102 on products and processes for chemical cleaning. *Chas. Pfizer & Co.*

75. Chill Treatment
Case histories of experience in chilling metals at −130 to −150° F. for stabilization and controlled ductility. *Harris Refrigeration Co.*

76. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

77. Chromium Plate
Data on chromium plate that can withstand fabrication. *American Nickeloid Co.*

78. Chromium Stainless
12-page book on fabrication and use of type 430 stainless steel. *Sharon Steel*

79. Coatings
4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

80. Cold Forming
4-page folder on die-form process for cold reduction of steel bars into multi-diameter shaft blanks for finish turning or grinding. *Republic Steel*

81. Cold Rolling
Description of advantages of cold rolling of ship propeller shafting. How it is done. *Erie Forge & Steel*

82. Compressors
12-page Bulletin 126-B on application of turbocompressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

83. Conveyor Belts
Report on service life of woven wire conveyor belts operating at temperatures of 2050° F. *Cambridge Wire Cloth Co.*

84. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

85. Corrosion-Resistant Alloy
16-page booklet gives chemical, physical and mechanical properties, high-temperature properties, and a guide to corrosion resistance of Hastelloy C. *Haynes*

86. Creep Testers
Article in Metal Digest, V. 4, No. 5, discusses creep testing machines for research and production. *Buehler, Ltd.*

87. Cutting Fluid
4-page folder on the development of

coolants from water to oil to chemical coolants containing no petroleum. Description of Hocut 237. *E. F. Houghton*

88. Cylinder Tubing
4-page booklet on cylinder tubing with smooth inside. Specifications. *Jones & Laughlin*

89. Deep Drawing
New catalog on line of draw presses for high-speed processes. Specification chart. *Steelweld Div., Cleveland Crane & Eng'g*

90. Degreaser
Folder on automatic degreaser. Cleaning and solvent cycles described. Features of equipment. *Detrex*

91. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

92. Degreasing
New 36-page bulletin 44A on trichlorethylene for vapor degreasing and other uses. Procedures in various equipment, properties, safety measures. *Hooker Chemical Co.*

93. Drilling
New booklet of case histories of applications of turret drilling machines. *Brown & Sharpe Mfg. Co.*

94. Drilling Machine
4-page catalog on new radial drilling machine shows construction, uses, specifications. *I. O. Johansson Co.*

95. Ductile Iron Plate
Data on ductile iron plate and properties. *Lindgren Foundry Co.*

96. Electrical Contacts
New 4-page condensed catalog on materials, properties, forms, uses of electrical contacts. *Gibson Electric Co.*

97. Electric Furnaces
Bulletin on furnaces for all types of heat treating and hardening, both standard and custom designed. *Pacific Scientific*

98. Electric Furnaces
12-page Bulletin SEC-3 on electric box-type furnaces for industrial batch-type applications. *Sunbeam Equipment Co.*

99. Electric Furnaces
New 12-page bulletin 461 illustrates and gives specifications on several models. *C. I. Hayes Inc.*

100. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

101. Electroplating
8-page bulletin on plating equipment and supplies includes test equipment. *Frederick Gumm Chemical Co.*

102. Electroplating
Chart gives reference data for gold, rhodium, palladium, platinum, silver, nickel plating. *Technic, Inc.*

103. Endothermic Atmospheres
16-page reprint on endothermic atmospheres for heat treatment of steel. Effect of temperature on atmosphere. Calculating analysis. *Electric Furnace Co.*

104. Environmental Testing
6-page brochure on uses of carbon dioxide for low-temperature environmental testing. *Pure Carbonic Co.*

105. Extruded Aluminum
New 12-page brochure on latest aluminum alloys, extrusion process and applications. *Precision Extrusions, Inc.*

106. Ferromanganese
New leaflet on manganese alloys gives compositions and uses of ferromanganese

briquettes and silicomanganese alloys and briquettes. *Vanadium Corp.*

107. Ferrous Metallurgy
8½ by 11-in. chart shows basic characteristics of steels from −300 to 2900° F. *Tempil° Corp.*

108. Finish
4-page folder on heat-resistant coating. Properties, performance data on black and aluminum Sicon coatings. *Midland Industrial Finishes Co.*

109. Flame Hardening
Bulletin tells how flame hardening improves rolls. Chart shows ranges, depth of hardness. *Detroit Flame Hardening*

110. Flame Plating
Brochure on process for coating hard materials. Also wallet-sized data card gives properties of several coatings. *Linde*

111. Formed Shapes
Catalog No. 1053 describing numerous formed shapes made from ferrous and nonferrous metals. *Roll Formed Products*

112. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

113. Furnace Controls
Bulletin 658 on saturable reactor for regulation and control of electric ovens and furnaces. *Sorgel Electric Co.*

114. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

115. Furnaces
List of used furnaces in stock. *Papesch & Kolstad, Inc.*

116. Furnaces
12-page catalog on electric heat treating furnaces. Data on each of 57 models. Controls, instruments, elements and accessories. *Lucifer Furnaces, Inc.*

117. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000° F. *Harper Electric*

118. Furnaces
12-page Bulletin No. 653A, describing range of electric and fuel-fired heat treating furnaces and protective atmosphere generators. Includes batch and nonferrous metals melting furnaces. *Hevi-Duty*

119. Furnaces
Bulletin 200 describes complete setup for heat treatment of small tools, including draw furnace, quench tank and high-temperature furnace. *Waltz Furnace*

120. Graphite
Folder on graphite crucibles, funnels, and special preformed electrodes. High-purity powder. *United Carbon Products*

121. Hardening Tool Steels
4-page bulletin on complete line of hydryzing furnaces. Diagrams, specifications and performance data on preheat and high-speed furnaces. *Lindberg Eng'g.*

122. Hardness Tester
Bulletin TT-59 on tester for measuring standard Rockwell and superficial hardness. *Wilson Mechanical Instrument*

123. Hardness Tester
Bulletin on Brinell tester with test head for deep and offset testing. *King Tester*

124. Hardness Tester
Bulletin S-33 on vertical-scale and dial-indicating scleroscopes. How they are calibrated. *Shore Instrument*

125. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

126. Hardness Tester
Catalog 506 on Frank hardness tester for Rockwell B and C, Brinell and Vickers hardness tests. *Opto-Metric*

127. Hardness Tester
4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

128. Hardness Tester
Data on portable hardness tester with Rockwell and Brinell scales. *Mechanical Devices*

129. Hardness Testers
Information on Tukon testers for microhardness and macrohardness testing. *Wilson Mechanical Instrument Div.*

130. Hardness Testing
Bulletin A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

131. Hardness Testing
20-page bulletin on Vickers machine. Description, accessories, advantages. *Riehle Testing Machines*

132. Heat Exchangers
New 12-page bulletin on impervious graphite immersion heat exchangers and steam jets. *National Carbon Co.*

133. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

134. Heating Elements
12-page bulletin gives typical applications of silicon carbide heating elements. Hints on handling, unpacking, storage, installation, replacement. *Globar Div., Carborundum*

135. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

136. Heat-Resistant Alloys
Data sheet on RA309 gives creep, stress-rupture and mechanical properties, composition. *Rolled Alloys, Inc.*

137. Heat-Resistant Castings
16-page bulletin on design, foundry practice and applications. *Electro-Alloys*

138. Heat Treating
Monthly bulletin on used heat treating and plating equipment available for immediate delivery. *Metal Treating Equipment Exchange*

139. Heat Treating
20-page catalog on the Homocarb method with Microcarb atmosphere control for heat treatment of steel. *Leeds & Northrup*

140. Heat Treating
Folder on shaker-hearth furnaces and push-through muffle furnaces for annealing, hardening and brazing stainless steel. *American Gas Furnace Co.*

141. Heat Treating
New 16-page bulletin on continuous plate and bar heat treating equipment, with methods and applications. *Drever*

142. Heat Treating Fixtures
16-page Catalog M-7 on heat treating baskets and corrosion-resistant alloy fabrications. *Wiretex Mfg. Co.*

143. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

144. Heat Treating Fixtures
32-page Catalog G-10A lists process equipment, heavy welded fabrications, muffles, trays, fixtures for furnaces, heat treating equipment, pickling equipment. *Rolock*

145. Heat Treating Furnaces
42-page catalog on line of furnaces and ovens for heat treating and accessory equipment. *K. H. Huppert Co.*

146. Heat Treating Supplies
Data sheets on carburizing, hardening, tempering, nitriding salts, metal cleaning and rust prevention materials. *Heatbath*

147. Heat Treatment
40-page booklet on structure and heat treatment of steel. Iron-carbon diagram. What happens when steel is heat treated. *Sandvik Steel*

148. Heat Treat Pots
Catalog on pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. *Eclipse Industrial Combustion*

149. High-Alloy Castings
16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

150. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

151. High-Strength Steel
48-page book on T-1 steel, its properties and applications. *U.S. Steel*

152. High-Strength Steels
New technical data brochure on high-strength high-temperature structural steels gives properties, heat treatment. *Universal-Cyclops Steel Corp.*

153. High-Temperature Alloy
Booklet "Keeping Costs Down When Temperatures Go Up". *International Nickel*

154. High-Temperature Alloy
14-page bulletin on Udimet 500 gives composition, heat treatment, machinability, hot working characteristics and properties. *Utica Metals Div.*

155. Hole Punches
Catalog AJ on hole punching units with cast steel holders. Punch sizes and hole sizes. *Punch Products Corp.*

156. Identifying Stainless
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel*

157. Induction Heating
Article on induction heating in zone refining, zone leveling and crystal growing, in High Frequency Heating Review, Vol. 1, No. 6. *Lepel High Frequency*

158. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

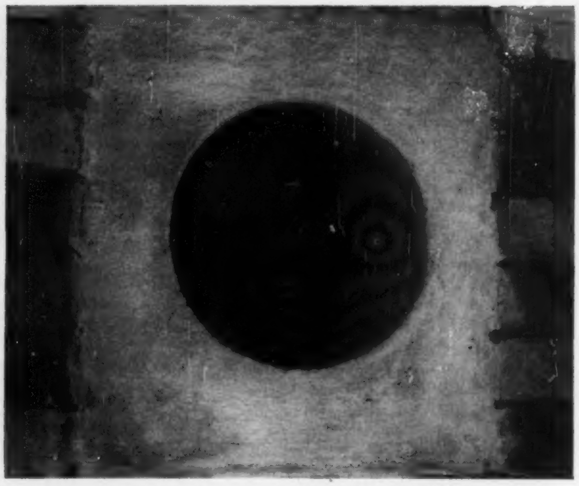
159. Induction Heating
12-page booklet on the ABC's of induction heating for extrusion, forging, brazing, heat treating and metal joining. *Ajax Magnethermic*

160. Infra-Ray Gage
Folder on new radiation-operated gage to measure width of hot strip at high speeds. *Daystrom-Weston Sales Div.*

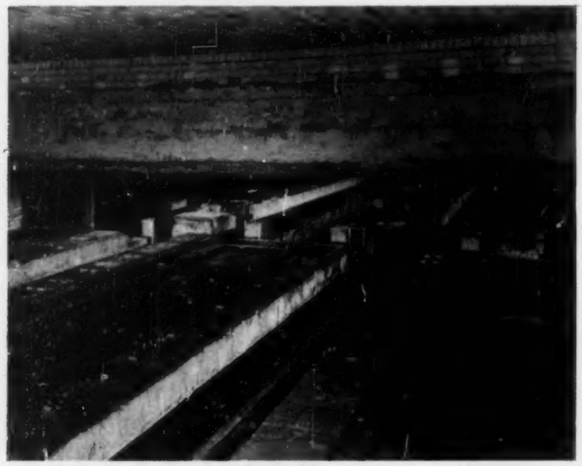
161. Ingot Molds
4-page bulletin describes a variety of molds for vacuum induction and controlled atmosphere melting. *Zak Machine*

162. Inspection
Data on ultrasonic inspection and thick-

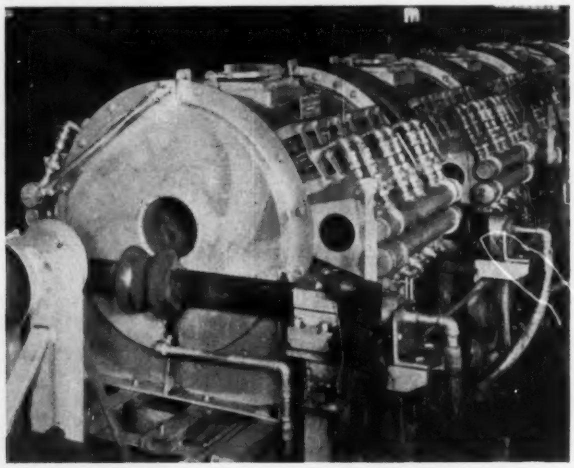
Electrode ports of this electric furnace roof are formed of B&W castable. B&W Kaocast or Kaocrete-32 can be successfully used, depending on severity of service.



High thermal release burner block is cast of B&W Kaocrete-32. Both Kaocrete-32 and Kaocast are used for burner blocks and other services in many other furnaces.



Nose arch of walking beam type furnace for heating forgings is made of Kaocast, B&W's 3000 degree castable. Kaocast is also used in forming complete forging furnaces.



This high speed barrel type heating furnace is typical of many which are completely lined with high temperature B&W Kaocast.

How B&W refractory castables solve high temperature problems

The higher temperatures in industrial processes have called for refractory castables that will stand up in these severe services. B&W offers two extremely durable, high temperature refractory products—Kaocrete-32 for applications up to 3200 F, and Kaocast with a 3000 F use limit. Both have high strength, unusual volume stability and excellent resistance to spalling and slag attack. Investigate B&W *specialized* refractory castables for solutions to your high temperature problems.

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R620R

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REFRACTORIES DIVISION

B&W Firebrick, Insulating Firebrick, and Refractory Castables, Plastics, Ramming Mixes, Mortars, and Ceramic Fiber.

ness measurement service in field or laboratory. *Sperry Products*

163. Insulation
16-page Bulletin R-2-H on insulating firebrick. Properties of six grades and applications of each. Design of arches and linings. *Refractories Div., B. & W. Co.*

164. Investment Casting
Data on investment cast alloys to operate between —400° F. and 2100° F. *Precision Castparts Corp.*

165. Investment Casting
"Pointing the Way" presents seven case histories on advantages of investment castings. *Engineered Precision Casting Co.*

166. Laboratory Equipment
Catalog on high-temperature laboratory ovens, construction, controls, accessories. *Modern Laboratory Equipment Co.*

167. Laboratory Equipment
Bulletin on cutting test specimens describes methods for different types of metals. Price list. *Sieburg Industries*

168. Laboratory Furnace
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

169. Laboratory Equipment
Data on cathodic vacuum etcher for metallographic samples, complex alloys and dispersions that are difficult to etch. *Nuclear Materials & Equipment Corp.*

170. Lathe Chucks
12-page catalog on geared scroll and independent hardened plate-type chucks gives specifications, uses. *Whiton Machine*

171. Leaded Steels
16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

172. Lubricant
8-page booklet, "Biggest Ounce of Protection", tells of lubrication with colloidal graphite products. *Grafo Colloids*

173. Lubricant
Bulletin 425 on colloidal dispersions for use in metal casting. Best formulas for achieving high lubricity and wetting action. *Acheson Colloids*

174. Machining Copper
32-page booklet gives cutting speeds, feeds, rakes, clearances for more than 40 copper alloys. *American Brass*

175. Magnesium
53-page book on wrought forms of magnesium includes 44 tables. *White Metal Rolling & Stamping Corp.*

176. Malleable Castings
Data Unit No. 105 on properties and characteristics that give standard and pearlitic malleable iron castings their toughness. *Malleable Castings Council*

177. Manganese
9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

178. Marking
Leaflet on where to use markers for identification purposes. *Markal Co.*

179. Measurement Systems
New 12-page bulletin on process industry measurement and control equipment. *Industrial Nucleonics Corp.*

180. Measuring Tools
New 96-page catalog of precision measuring tools and instruments. Illustrations, price list. *Scherr-Tumico Co.*

181. Metal Cleaning
Folder lists products for immersion, electrolytic, spray cleaning, other cleaning agents. *Northwest Chemical*

182. Metal Forming
Folder on rolling mills, swaging machines, wire shaping mills, wire and tube drawing machines. *Fenn Mfg.*

183. Metallograph
12-page bulletin on desk-type and research metallographs. Accessories, illuminating systems, specifications. *American Optical Co.*

184. Metallograph
Folder on Mark IV metallograph gives advantages, specifications. *Cooke, Troughton & Simms, Inc.*

185. Metal Powders
New 8-page brochure gives information on prealloyed metal powders and tool steels used in powder metal parts production. *Vanadium-Alloys Steel Co.*

186. Metal Sorting
Data on nondestructive sorting of raw, semifinished or finished parts. *J. W. Dice*

187. Microhardness
Data on microhardness tester with readings corresponding to Vickers. *Newage*

188. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance*

189. Microscopes
6-page bulletin M29 on inverted microscopes gives objectives, eyepieces, filters. Cameras described. *Cooke, Troughton & Simms, Inc.*

190. Mills
Two designs of size-reduction equipment described in new 4-page Bulletin No. 350. *F. J. Stokes Corp.*

191. Multi-Arc Welding
71-page "Guide to Better Welding" covers technology, economics and other aspects of multi-arc welding. *J. B. Nottingham & Co.*

192. Nickel-Base Alloy
Technical Data series No. 86 on René 41, vacuum-melted nickel-base alloy. Properties. Temperature range 1200 to 1800° F. *Cannon-Muskegon*

193. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

194. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

195. Nuclear Graphite
8-page bulletin tabulates properties, high-temperature strength, corrosion resistance, thermal conductivity, machinability. *National Carbon*

196. Oil Quenching
Catalog FB-1052-A on self-contained oil cooling equipment. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

197. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

198. Ovens
14-page Bulletin No. 53-CM on various types of core and mold ovens. Construction, operating principle, advantages. *Carl-Mayer*

199. Ovens
Bulletin 4-257 on gas, oil and electric ovens. Load-carrying-door, electric-drawer and walk-in type ovens. *Grieve Hendry*

200. Particle Inspection
New 36-page booklet on agent for wet

(Continued on page 48-A)

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Armour Anhydrous Ammonia has a guaranteed minimum purity of 99.98%. Ammonia so pure, you have no problems with moisture, oil or non-condensable gases.

You are always assured of excellent heat treating results, because Armour quality standards are based on an extra control test made when the ammonia is ready for shipment to you. *Every* cylinder and tank truck of Armour Ammonia is subjected to a rigid qualitative test after filling to make sure it is *at least* 99.98% pure *when delivered* to you. This extra Armour test eliminates the danger of your receiving ammonia that has been contaminated during the filling process.

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(Continued from page 47)

magnetic particle inspection. Case histories compare special methods and effectiveness. *Harry Miller Corp.*

201. Parts Production
Data on forging, machining and finishing facilities for parts production. *H. K. Porter, Forge & Fittings Div.*

202. Peening
Folder on process and equipment for peening, cleaning, finishing. *Perfecto-Peen Div., Aero-Test Equipment Co.*

203. Plating
9-page bulletin on copper fluoborate bath for printed circuits. Bath composition, make-up and control for copper and tin plating. *Baker & Adamson*

204. Plating
8-page brochure on test equipment for plating baths. Controls, anodes, cathodes, agitators, rectifiers. *R. O. Hull*

205. Plating Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

206. Powdered Iron
12-page Bulletin No. 2 on iron powders. Properties of Plast/Iron, Plast/Steel, Plast/Nickel, Plast/Manganese and Plast/-Silicon. *Plastic Metals Div.*

207. Powdered Metals
Folder on how powdered metal parts can replace machined parts. *Norwalk Powdered Metals, Inc.*

208. Powder Metallurgy
16-page booklet on advantages and disadvantages of process, design data, materials used. *Reese Metal Products*

209. Power Convection
8-page folder on heat treating furnaces using the principle of power convection. *Surface Combustion Corp.*

210. Precious Metals
Revised 10-page brochure on solid and clad metals, electrical contacts, numerous plate products. *Metals & Controls Div., Texas Instruments*

211. Precipitation-Hardening Stainless
New 24-page booklet on properties, treatment, fabrication of aircraft steels AM 350 and AM 355. *Allegheny Ludlum*

212. Precision Plating
4-page brochure describes process for plating selected areas without immersion tanks. *Sifco Metachemical*

213. Presses
12-page brochure on horizontal, multi-station, automatic redraw presses. Details on 12 machines; advantages of multiple-station deep drawing; attachments. *Waterbury Farrel Foundry & Machine*

214. Radiation Products
8-page catalog on equipment for nuclear research. Radioactive sources, shielding and exposure equipment, instruments, services. *Budd Co.*

215. Radiography
16-page booklet on materials and accessories for industrial radiography. Guide to selection of film. Recommended development techniques. *Eastman Kodak, X-Ray Div.*

216. Radiography
New 12-page booklet on equipment and methods of radiographing industrial products with radioisotopes. *Picker X-Ray*

217. Recorders
Bulletin F-8938 on series 2000 and 3000 potentiometer recorders. Specifications. *Wheelco Instruments Div.*

218. Recorders
New electronic indicating recorders and controllers described in 4-page bulletin No. 66. *Thermo Electric Co.*

219. Refractories
Revised Brochure IN-115A on products for casting special refractory shapes and for gunning and troweling applications, service to 3000° F. *Johns-Manville*

220. Refractories
12-page catalog shows properties of impervious recrystallized alumina and impervious mullite. Shapes into which each is fabricated. *Morganite, Inc.*

221. Refractories
40-page book lists superrefractories for heat treating furnaces and gives data on use in different kinds of furnaces. *Refractories Div., Carborundum*

222. Rolling Mills
Data on 2-high/4-high combination rolling mill for metallurgical production and research. *Loma Machine Mfg. Co.*

223. Rust Prevention
20-page booklet on causes of rust and application of preventives. Data on rust preventing liquids and recommended applications. *Rust-Lick, Inc.*

224. Rust Removal
Folder on new alkaline cleaning material for removal of rust, certain types of heat scale and metallic smuts. *Oakite*

225. Shaped Tubing
Square, elliptical, rectangular and many other cross sections of tubing described in Data Memo No. 17. Applications, ordering information. *Superior Tube Co.*

226. Shot and Grit
New brochure "Facts of Life Concerning the Use of Shot and Grit" tells of blast cleaning functions and materials, research achievement in manufacture of shot and grit. *National Metal Abrasive*

227. Shuffle-Hearth Furnace
4-page folder gives performance, features of new furnace for production heating and quenching. *Sunbeam Equipment*

228. Slitter
16-page booklet on rotary gang slitters. Sheet and coil slitting methods summarized. *Stanat Mfg.*

229. Slitting Equipment
Revised 76-page catalog on design, selection and operation of slitters and slitting lines, time analyses, operating cycles. *Yoder Co.*

230. Sodium Wire
8-page bulletin on process for converting metallic sodium into wire. *U. S. Industrial Chemicals Co.*

231. Soldering Fluxes
4-page bulletin on line of nonacid self-cleaning fluxes. How they work. *Lake Chemical Co.*

232. Spectrograph
New 8-page booklet on automatic indexing X-ray spectrograph. Engineering data, operating principles and procedures, performance, calibration. *Philips Electronics*

233. Stainless Castings
Bulletin on advantages of corrosion-resistant castings. *Ohio Steel Foundry*

234. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

235. Stainless Steel
New handbook of wire, rod, strip. Properties, specifications, applications. *Riverside-Alloy Metal Div. H. K. Porter*

236. Stainless Steel
12-page booklet on new AM-350 chromium-nickel-molybdenum stainless steel which is hardenable by subzero cooling or double aging. *Allegheny Ludlum*

237. Stainless Steel
Properties and selection of stainless steel wire, rod, strip. *Riverside Alloy Metal Div., H. K. Porter Co.*

238. Stainless Steel
Pocket card gives instructions for mak-

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ing a chemical spot test to distinguish 200 series from 300 series stainless steels. *Union Carbide Metals*

239. Stainless Steels
File-type data chart compares properties of 18 grades of stainless. *Peter A. Frasse Co.*

240. Steel Bars
Wall chart lists 241 AISI grades of cold finished steel bars and gives their analysis. *LaSalle Steel*

241. Steelmaking
24-page booklet on melting, forging, heat treating, machining and other facilities. Type of products produced. *Midvale-Heppenstall Co.*

242. Steelmaking Additive
Data on additive which cleans melts without changing analysis. *WaiMet Alloys*

243. Stock Straightener
Folder on operation and advantages of new stock straightener. *H. E. Dickerman Mfg. Co.*

244. Strain Measurement
Brochure on new monofilament strain gage, with applications, test information. *High Temperature Instruments Corp.*

245. Superalloys
Two new bulletins on performance of vacuum induction melted Waspaloy and M-252 alloys. *Metals Div., Kelsey-Hayes*

246. Surface Finish Testing
New 12-page catalog on instruments for measuring surface roughness including those for measuring in small holes, grooves, gear teeth. *Micrometrical Mfg.*

247. Temperature Control
New 4-page data sheet No. 660 (2) on control system for brazing honeycomb panels. *Leeds & Northrup Co.*

248. Temperature Control
24-page article on temperature control of heat treating furnaces. Control instruments, elements and systems. *General Electric Co.*

249. Temperature Control
8-page bulletin on temperature control systems contains selection guide, terminology, types of control systems. *Wheelco Instrument Div.*

250. Temperature Control
Bulletins on differential expansion units for automatically controlling temperatures and serving as safety limit switches. *Burling Instrument Co.*

251. Tensile Testing
4-page booklet on line of tensile testing machines with capacities to 40,000 lb. *Steel City Testing Machines*

252. Test Equipment
Catalog R-36A on complete line of testing equipment, including all industrial electronic and electrical equipment. *Daystrom-Weston*

253. Testing
Brochure on facilities for metallurgical testing. Methods of analysis of high-temperature alloys. *Frank L. Crobaugh*

254. Testing Furnaces
New illustrated catalog on line of metallurgical testing furnaces, ovens and accessories. *Marshall Products Co.*

255. Thermocouple Insulators
Bulletin No. 300-56 on complete line of thermocouple insulators. Dimensions, sizes, types of insulators. *Claud S. Gordon*

256. Thermocouples
16-page catalog on industrial thermocouples, protecting tubes, extension lead wires, thermocouple wires, insulators, terminal heads, and accessories. *Arklay S. Richards*

257. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

258. Tin
20-page bulletin on importance of tin to the American industry. Applications in aircraft, chemical, container, electrical, electronic equipment and others. *Malayan Tin Bureau*

259. Titanium
36-page technical handbook on corrosion-resistant properties of titanium and its design and fabrication characteristics. *Titanium Metals Corp.*

260. Tube Furnaces
Bulletin 559 on tube furnaces for tensile and creep testing machines. *Hevi-Duty Electric Co.*

261. Tubing
4-page folder on advantages of alloy mechanical tubing. *Tubular Products Div., Babcock & Wilcox*

262. Tubing
Special Analysis Memo No. 121 on tubing of columbium, tantalum, vanadium. Applications, properties. *Superior Tube*

263. Ultrasonic Cleaning
24-page Bulletin S-200 explains practical applications and basic principles of ultrasonic cleaning. Design of equipment. *Branson*

264. Ultrasonic Cleaning
Primer on ultrasonic cleaning, applications, compounds, metal cleaning principles. *National Ultrasonic Corp.*

265. Ultrasonic Degreaser
Flier on new model ultrasonic degreaser. Features and specifications. *Princeton Div., Curtiss-Wright Corp.*

266. Ultrasonic Inspection
Data on new ultrasonic flaw detector with details on sensitivity, resolution and frequency. *Branson Instruments, Inc.*

267. Vacuum Furnace
New Data Sheet 660 on a vacuum melting furnace with melt capacity of 50 lb. *F. J. Stokes*

268. Vacuum Processing
Data sheet on bell jar unit gives applications, pumping system, optional equipment, specifications. *High Vacuum Equipment Corp.*

269. Vacuum Pumps
68-page Bulletin 6-1 on high vacuum vapor pumps. Describes technique and pumping systems. Tables, charts and graphs. *Rochester Div., CEC*

270. Vacuum Pumps
Bulletin 3180.1 on mechanical booster high-vacuum pumps gives application, performance data, a specification chart. *Kinney Mfg. Div.*

271. Voltmeters
New bulletin E111 describes new models, operating principles, list of charts and accessories for voltmeters and ammeters. *Bristol Co.*

272. Welding Equipment
New 20-page catalog on Heliarc line of manual welding equipment and accessories. *Linde Co.*

273. Welding Tantalum
Illustrated article on arc welding tantalum by tungsten inert-gas process in Fansteel Metallurgy, July 1959. *Fansteel Metallurgical Corp.*

274. Welding Titanium
8-page technical brochure on the arc welding of titanium. Lists grades of pure titanium and titanium alloys which can be welded. *Mallory-Sharon Metals*

275. X-Ray Inspection
Folder on 300 kvp. inspection unit. Cutaway diagram. Basic designs. *General Electric, X-Ray Dept.*

276. Zinc Coating
8-page booklet on zinc-coated steel sheets. Fabrication, uses, advantages in heating, ventilating and air conditioning. *Weirton Steel*

JANUARY, 1960

1	24	47	70	93	116	139	162	185	208	231	254
2	25	48	71	94	117	140	163	186	209	232	255
3	26	49	72	95	118	141	164	187	210	233	256
4	27	50	73	96	119	142	165	188	211	234	257
5	28	51	74	97	120	143	166	189	212	235	258
6	29	52	75	98	121	144	167	190	213	236	259
7	30	53	76	99	122	145	168	191	214	237	260
8	31	54	77	100	123	146	169	192	215	238	261
9	32	55	78	101	124	147	170	193	216	239	262
10	33	56	79	102	125	148	171	194	217	240	263
11	34	57	80	103	126	149	172	195	218	241	264
12	35	58	81	104	127	150	173	196	219	242	265
13	36	59	82	105	128	151	174	197	220	243	266
14	37	60	83	106	129	152	175	198	221	244	267
15	38	61	84	107	130	153	176	199	222	245	268
16	39	62	85	108	131	154	177	200	223	246	269
17	40	63	86	109	132	155	178	201	224	247	270
18	41	64	87	110	133	156	179	202	225	248	271
19	42	65	88	111	134	157	180	203	226	249	272
20	43	66	89	112	135	158	181	204	227	250	273
21	44	67	90	113	136	159	182	205	228	251	274
22	45	68	91	114	137	160	183	206	229	252	275
23	46	69	92	115	138	161	184	207	230	253	276

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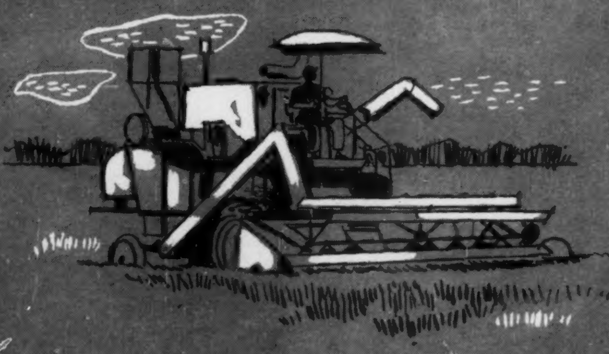
two more cases where PARTS PRODUCED FROM provide excellent bearing properties

CASE HISTORY

MUELLER BRASS CO. 600 ALLOY screw machine product used in heavy duty farm equipment

This heavy duty planetary pinion shaft, made as a screw part from tough "600" series bearing alloy, was the answer to a continuing wear problem encountered in the driving mechanism of heavy-duty farm equipment and big trucks. The part is machine produced to exacting tolerances and all necessary finishing operations are done by Mueller Brass Co. so the pinion shaft is ready for installation when received. Since "600" alloy parts have been installed, no operating failures have been reported and the shafts have proved far superior to the material formerly used.



MUELLER BRASS CO. ANALYSIS SERVICE

You get sound, unbiased advice on the one best method of making your parts because Mueller Brass Co. is the only fabricator in the country offering all these methods of production. An experienced Methods Analysis Department has at its command a complete knowledge of the advantages and limitations of each production process. This unique technical service is your assurance of getting the best product at the best price . . . made the one best way!

COLD-PREST IMPACT EXTRUSIONS

PLASTIC INJECTION MOLDING

MUELLER BRASS CO.

MUELLER BRASS CO. 600 ALLOY

and maximum wear resistance in tough applications

CASE HISTORY

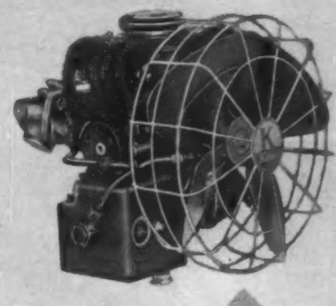
MUELLER BRASS CO. 600 ALLOY forgings used in aviation air compressors

Analyzing the job requirements of Walter Kidde & Company, Inc., for a main driving cam component to be installed in a reciprocating type of aircraft air compressor, Mueller Brass Co. Methods Analysis Engineers decided on a forging fabricated from "600" alloy as the most practical method of production. Since the cam forms the prime component of the driving mechanism, it must have good bearing wear surfaces and because the compressors are used in the aviation industry, the cams must be completely dependable. The close grained, strong forging that resists combination compressive and tensile stresses was the answer.

A typical compressor takes in ambient air and compresses it to 3000 psi or higher. This high pressure air is stored in metal or fiberglas containers until needed for actuation of pneumatic system components such as solenoid control valves, brake valves, manual control valves or actuators. These and other pneumatic units retract the entrance door, operate landing gear, wheel brakes, nose wheel steering systems, propeller brakes or perform other functions.

Aircraft in which Kidde compressors are installed include the Boeing 707, the Douglas DC-8, the Lockheed Electra, the Fairchild F-27 and various military aircraft.

Mueller Brass Co. produces press, hammer or cored forgings of any practical shape from a few ounces to 150 lbs. in brass, bronze, aluminum and magnesium in 27 standard, as well as special, alloys.

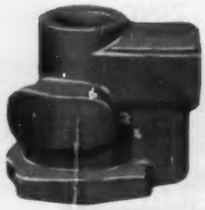


Aircraft air compressor equipped with hydraulic drive delivers air compressed to 3000 psi at the rate of 6 cfm.

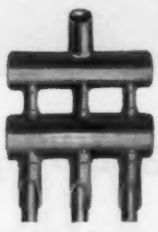
This yoke forging is lightweight, yet strong; has excellent bearing wear surfaces.

Forging is part of the main cam, the prime component of a modified Scotch-type yoke, which is the piston driving mechanism in the air compressor.

POWDERED METAL PARTS



SAND CASTINGS



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Make speedier checks of recorders, controllers and base or noble metal thermocouples in industrial plants with the new three-dial 8686 Portable Millivolt Potentiometer. Features such as a central reading window . . . where measured values appear as a row of digits with a scale interpolation . . . simplify calibration of thermocouples and test measurements. The 8686 Potentiometer has: a wide operating range of −10.0 to +100.1 mv and +1010 to +1020 mv for standard cell calibration; and a high accuracy of ±(0.05% of reading +3μv) without reference junction compensation, ±(0.05% of reading + 6 μv) with ref. jct. comp. Write for Data Sheet E-33(1A).

8686 Millivolt Potentiometer

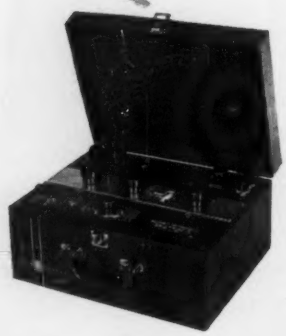
8690 Millivolt Potentiometer

Fast, accurate in-plant checking of thermocouples, recorders and controllers is expedited by the new 8690 Portable Millivolt Potentiometer. Design features such as "Inline Readout", which permit measured values to be read in digits with a scale interpolation, accelerate temperature measurements. The 8690 provides a wide range of −11.0 to +101.0 mv which eliminates input reversals; an accuracy of ±(0.05% of reading + 20 μv) without reference junction compensation, ±(0.05% of reading + 40 μv) with ref. jct. comp. Write for Data Sheet E-33(1B).

4 time-saving instruments from the

NEW

CONVENIENCE-STYLED L&N LINE . . .



8692 and 8693 Temperature Potentiometers

If you want to make a variety of temperature measurments quickly with one flexible instrument, investigate the new time-saving 8692 Single-Range or 8693 Double-Range Temperature Potentiometers. Available in any of 24 interchangeable temperature and millivolt ranges, these instruments read directly in degrees F or C on a scale 27½" long. Convenience features include: simplified range changes . . . only a screwdriver is needed to change a circuit panel, scale and binding post studs; automatic reference junction compensation . . . reference coil, built into circuit panel, compensates for thermocouple being used; accuracy . . . ±0.2% of range. Write for Data Sheet ND42-33(1A).

Need a fast-operating, high-sensitivity, high-quality null indicator for use in research, testing and production checking? Here's a new 9834 Guarded D-C Null Detector having a short period of less than two seconds for source resistances up to 1000 ohms, increasing to 4 seconds at 100,000 ohms . . . ideal for measurements with guarded or unguarded potentiometers and bridges. Of rugged construction, this portable, line-operated detector provides numerous convenience features which include four degrees of sensitivity, with a basic sensitivity of 0.2 μv/mm (0.3 μv/scale div.), and a noise level of less than ±0.1 μv. Write for Data Sheet ED7(2).

9834 Guarded D-C Null Detector

LEEDS & NORTHRUP

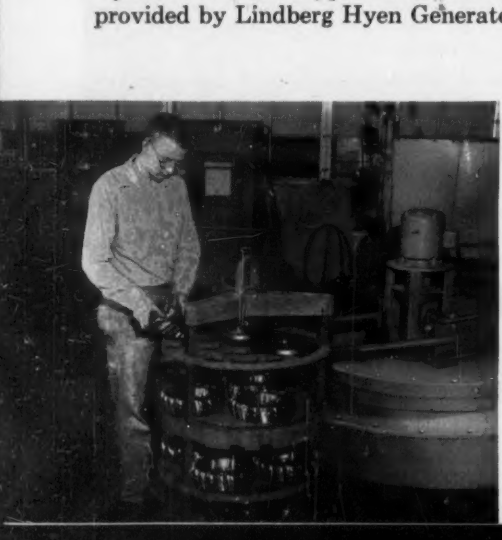
4927 Stenton Ave., Philadelphia 44, Pa.

This Lindberg Furnace, Model CT3848-A, is being used at Ingersoll Milling Machine Company, Rockford, Illinois, for hardening Ingersoll inserted blade milling cutter bodies and also for gas carburizing. It is equipped with Lindberg's exclusive CORRTHERM electric heating elements. Temperature range 1850° to 2000°F.

THIS VERSATILE LINDBERG FURNACE BELONGS IN MOST ANY METAL WORKING OPERATION

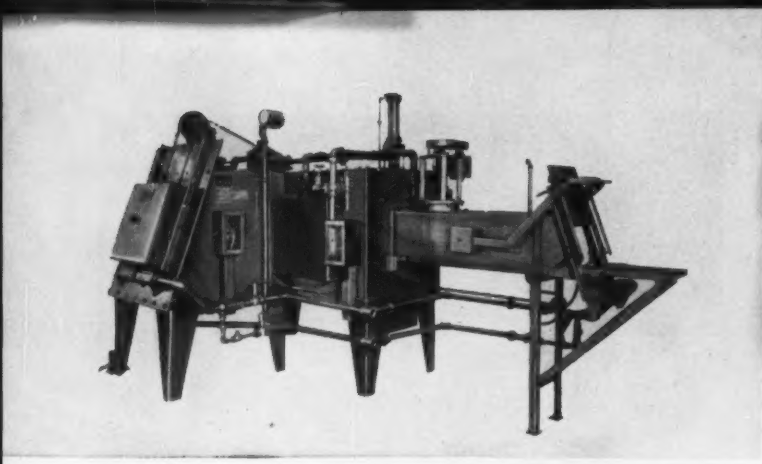
Heat treating installations across the country, captive or commercial, have found the versatility and dependability of this Lindberg furnace, either electric or fuel fired, a great production asset. Used at Ingersoll for hardening and carburizing, it is also ideal for a variety of heat treating needs including normalizing, annealing and tempering. This furnace occupies little floor space, handles a large volume of production and its rugged construction keeps maintenance costs uniformly low. At Ingersoll, it is one of several Lindberg furnaces in regular operation. Others include pit and box type Lindberg Cyclones and an L-type Furnace. Atmospheres are provided by Lindberg Hyen Generators.

Lindberg has developed a wide variety of equipment for any industrial heat treating requirement. We provide everything from individual furnaces to complete, automated heat treating installations. These can either be factory-built or installed in your own plant. For the most satisfactory answer to any heat treating problem see your local Lindberg field representative (consult your classified phone book) or write direct to Heat Treating Division, Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois. Los Angeles Plant: 11937 South Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg, Limited, Toronto.

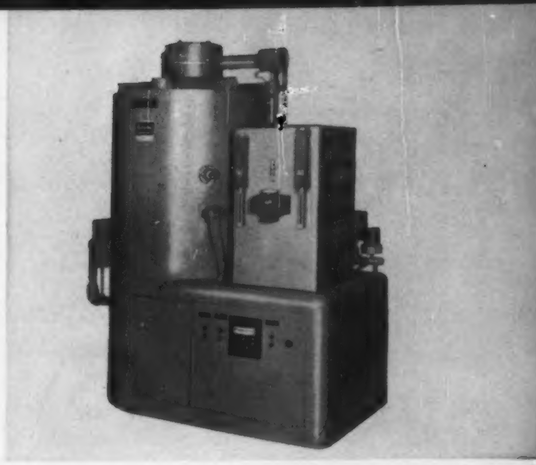


Fixture being loaded with work while furnace is treating another load. Treated load will be removed and new load inserted quickly and easily.

CORRTHERM heating elements operate at extremely low voltage so heat leakage through carbon saturation is eliminated and shock or short hazard prevented. Makes possible use of electricity for carburizing without furnace retort.

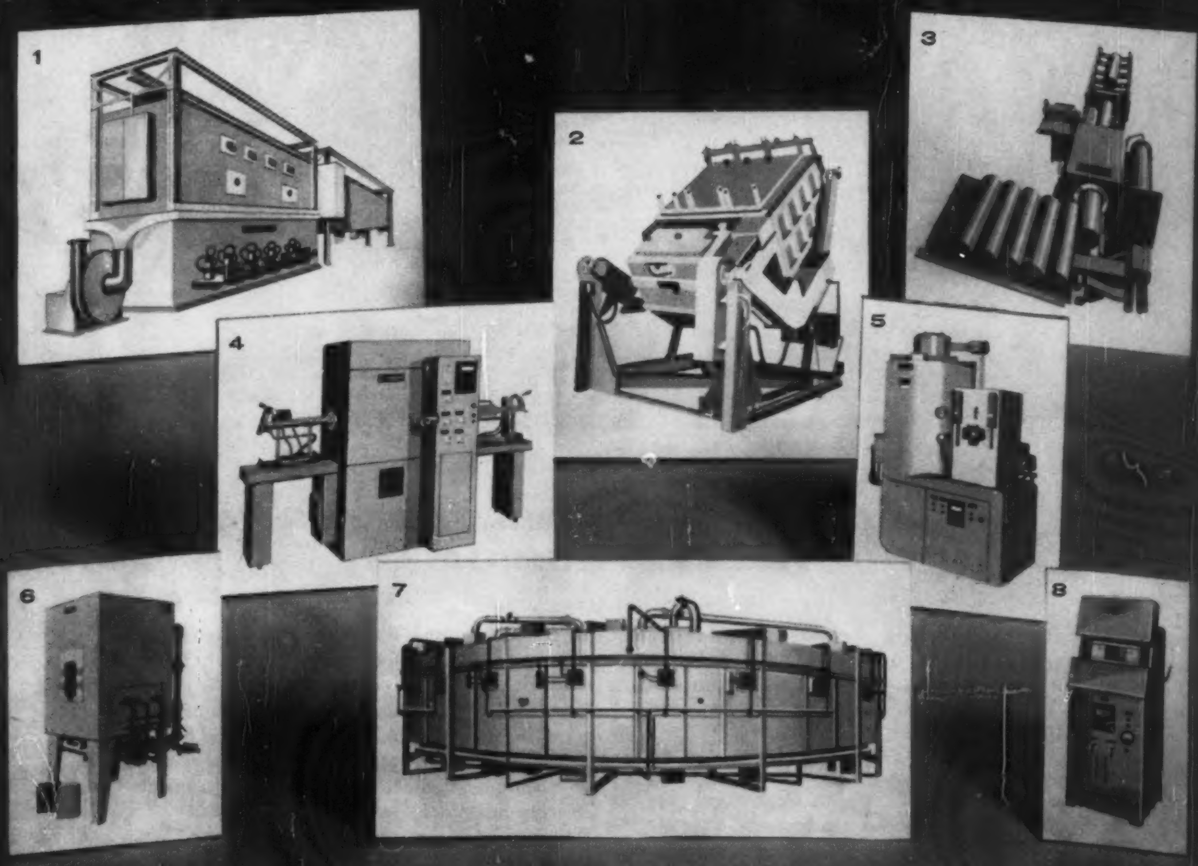


The Lindberg installation at Ingersoll includes one of our L-type Furnaces, ideal for treating high speed steel.



Atmospheres for Lindberg furnaces at Ingersoll are provided by Lindberg's Hyen Generator, a fully automatic process for producing endothermic atmospheres.

THERE'S LINDBERG EQUIPMENT FOR EVERY INDUSTRIAL HEATING NEED



1 **Salt Bath Furnaces:** Complete line of Lindberg-Upton equipment for all types of salt bath treatment. Shown: Installation for aluminum dip brazing.

2 **Melting and Holding Furnaces:** Equipment for any non-ferrous metal requirement including electric resistance and induction reverberatories, crucible and two chamber induction units. Shown: 350 KW Induction Furnace with 30,000 lb. capacity.

3 **High Frequency Units:** Complete range of induction heating units and furniture. Shown: New Induction Billet Heater for aluminum extrusions.

4 **Pilot Plant Equipment:** Complete group of intermediate sized furnaces for pilot plant and small production application. Shown: New Graphite Tube Furnace, temperature range 2500°F. to 5000°F.

5 **Atmosphere Generators:** Generators for all required furnace atmospheres. Shown: Hyen Generator for endothermic atmospheres.

6 **Ceramic Kilns:** All types of kilns: automatic, atmosphere controlled, high temperature, tunnel and periodics. Shown: Periodic Kiln, temperature range to 3250°F.

7 **Heat Treating Furnaces:** For every requirement, large or small, electric or fuel fired, factory built or field-installed. Shown: Rotary Hearth Furnace field-installed by Lindberg Industrial Division.

8 **Laboratory Furnaces:** Complete line of laboratory furnaces from simple hot plates to specialized research units. Shown: Versatile, wide temperature range Laboratory Box Furnace.

For full information on any type of Lindberg equipment see your local Lindberg field representative (look in your classified phone book) or write to Lindberg Engineering Company, 2448 W. Hubbard Street, Chicago 12, Illinois.

LINDBERG heat for industry

no. 9 OF A SERIES

OLDSMOBILE "TOES THE MARK" ... ELECTRONICALLY!

Oldsmobile Engineering Leadership sets the industry pace with a unique electronic wheel alignment device that dynamically computes "toe-in" measurements for precision steering and handling.

Handling and steering ease depend upon precise, minute measurement and control of front wheel alignment. Because wheels have a tendency to "toe-out" when in motion, they must be adjusted for a slight amount of "toe-in" to eliminate "wheel fight", wander and undue tire wear.

To meet the requirement of rapid, yet extremely accurate measurements on the production line, Oldsmobile engineers developed an electronic computor—a *linear-differential-variable transformer*—that dynamically and accurately measures the average amount of toe-in within .030 inches. As the car is brought into position, the wheels are rotated by rollers to simulate actual driving conditions and to eliminate errors caused by variations in tire run-out. By watching the visual gauges, an operator can quickly make the necessary adjustments to the steering linkage.

By using the most up-to-date electronic measuring techniques in engineering and manufacturing, Oldsmobile is able to offer safe, accurate steering and handling . . . a controlled, comfortable ride. Visit your local Oldsmobile Quality Dealer, take a ride in a '60 Oldsmobile and see why it's the value leader of its class!

OLDSMOBILE DIVISION • GENERAL MOTORS CORPORATION

OLDSMOBILE **Where Proven Quality is Standard!**

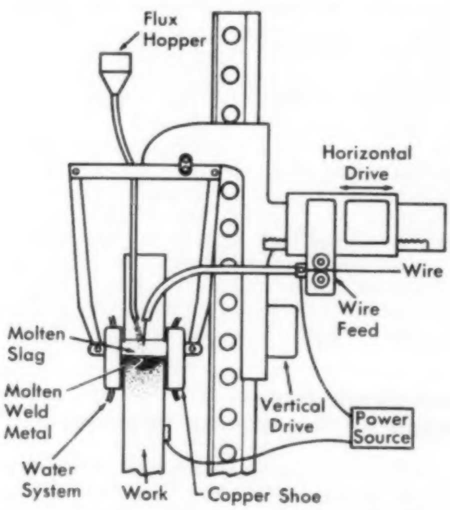
Technical NEWS in Brief

Electroslag Welding Comes to U.S.A.

If you fabricate heavy equipment, you will be interested in electroslag welding – an arcless technique which can weld joints over 1½ in. thick in one pass. Developed in Russia, the method has been widely applied there and in Europe.

Last month the process made its bid in the U.S. when Arcos Corp., Philadelphia, unveiled equipment for electroslag welding which it will sell and service. Machines available here will apply the same working principle (see diagram) reported by the Russians: A consumable wire electrode is melted by a molten slag, rather than an arc, as in submerged-arc welding.

To start the welding process, flux is heated to its melting point by striking an arc in a U-shaped



How Electroslag Welding Works
Automatic Equipment Joins Heavy Sections in One Pass

tab which forms an extension of the vertical joint. When sufficient slag is melted the arc is killed by changing the characteristics of current flow. Electrical resistance of the liquid slag causes heating and maintains the slag temperature at about 3500° F. – enough to melt the wire and the adjacent parent metal. The metal then collects in a liquid pool beneath the protective layer of molten salt. Depth of the slag is kept at about 1½ in., the metal pool at about ½ in.

For vertical welding of heavy sections – the most promising applications of the electroslag process – the pieces to be joined are spaced about 1 in. apart. Slag and metal bath are confined to the joint by water-cooled copper shoes placed on each side of the joint. The entire apparatus – shoes, flux hopper, wire feed control, vertical drive – moves upward as a unit on a pole.

Welding is Fast – Deposition rate with a single electrode is up to 45 lb. per hr., but in effect electroslag welding compares more favorably with other processes than this figure indicates. This is because the new method is not only automatic but also is a one-pass operation which continues uninterrupted until the complete joint is welded. No shut-downs are necessary to knock off slag, for example.

Price of equipment with a transformer capable of handling one wire electrode is about $18,000. Equipment is also built to take a three-wire simultaneous feed for very thick sections (9 to 16 in.). Additional transformers – one is needed for each wire – are available for $3000 each. (A detailed report on electroslag welding in Russia and the United States will appear in *Metal Progress* next month.)

Notes From Electric Furnace Conference

• **Roofs made of 70% alumina brick,** now being substituted for silica roofs in electric furnaces, last three to four times as long, according to reports given at the Electric Furnace Steel Conference (A.I.M.E.) held in Cleveland last month. However, such roofs bring new problems: Better electrical conductivity of alumina results in arc-over between carbon electrodes and cooling rings. As a result, rings made of castable refractories are being substituted for the hollow metal rings to reduce the deterioration caused by this arc-over. Progress is being made but there is need for further work.

• **Consumable electrode melting** is another area receiving attention from the furnace men. For

example, control systems are being studied. According to R. P. Morgan, Union Carbide Metals Co., Niagara Falls, N.Y., it may be possible to eliminate the direct-viewing feature now needed in controlling arc length. When an oscilloscope is connected across the terminals, the signal trace impressed on the screen will vary in accordance with the type of arc. Thus, if the arc begins to misbehave, its signal changes, and the operator knows that adjustments are needed. When fully developed, a system of this sort, Dr. Morgan says, will be much less expensive than the elaborate optical setups now in use.

• **A simple vacuum degassing system** for small foundries was reported by J. K. Dietz, Martin Co., Denver, Col. In essence, it consists of a shell with attached pump-down equipment. The shell can be placed over a small induction furnace containing a molten heat. As the vacuum is drawn, the heat is degassed. According to Mr. Dietz, two California foundries have assisted in developing this setup, working under government contract. So far, vacuums down to 600 microns have been achieved. Though this value is rather high, good degassing is possible, particularly for hydrogen. In four typical heats of Type 347 stainless steel, hydrogen was reduced from averages of 4.1 to 5.3 ppm. down to 2.2 to 2.6 ppm. Nitrogen and oxygen have also been reduced appreciably by this setup.

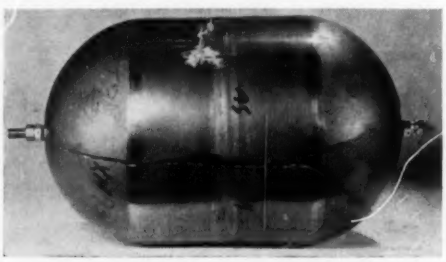
Rocket Motor Cases: Renewed Hope for Titanium

Titanium is in the running in the search for metals suitable for high-strength rocket cases, according to metallurgists at Pratt & Whitney Aircraft. Asked by the Air Force to select an alloy capable of developing a yield strength-to-density ratio of 1,000,000, P & W decided after careful evaluation that the new beta alloy (13 V, 11 Cr, 3 Al, balance Ti) showed great potential. Beta can be cold worked and aged to a yield strength of 180,000 psi. with elongation of 5 to 10%. At this stress level, beta reaches the 1,000,000-to-1 yield strength-to-density ratio and on this basis it is equivalent to steel with 280,000 psi. yield strength.

But fabrication and welding characteristics are just as important as strength and elongation. At a symposium on rocket motor cases P & W expressed optimism on beta's potential in these respects too. The alloy develops the desired strength after cold working and aging. The relative simplicity of heat treatment is itself an advantage since machined rocket cases will not tolerate high temperatures and quenching if distortion and handling problems are to be kept to a minimum.

Basically the rocket motor case consists of a flow-turned cylinder to which forged and machined end closures are welded. Preliminary work indicates that satisfactory strength and ductility (about 180,000 psi. yield and at least 5% elongation) can be obtained after aging when billets are forged and pressed to make the dome-shaped end closures and when roll-forged rings are flow-turned to form the cylinders.

Major problem is welding and experience shows it must be done with special care. For the time being P & W expects to leave welds in the more ductile as-welded condition although cold working improves strength. Stress-relief by local induction heating may be required if residual stresses prove too high. Weld metal should also be cooled with helium gas to insure a fine-grained structure.



Burst Test on Beta Pressure Vessel
Twelve of Sixteen Vessels
Have Exceeded 200,000 Psi. Stress

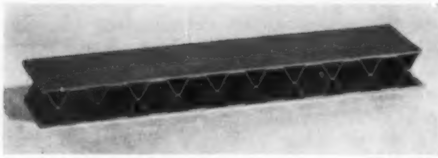
New Electron Emission Microscope

At the 25th Anniversary celebration of Max Planck Institute's Metallforschung late in November, described in some detail by Sam Hoyt in the Correspondence pages, Professor Duker discussed his new electron emission microscope. The electron beam is produced by bombarding the specimen with ions, and the beam is focused on a plate or motion picture film. The fine microstructure of the specimen can thus be revealed, and since this can be done with a hot specimen, phase transformations can be photographed, either as stills or on motion picture frames. For example, when viewing iron at the Ac_3 point one can see alpha changing into gamma and back again as the temperature is gradually lowered and raised. In other alloys precipitates can be dissolved and then reappear. The theoretical resolution is 150 Ångstroms though the practical limit is somewhat larger.

Sandwich Panels Made by Resistance Welding

As operating conditions imposed on supersonic aircraft become more severe, engineers may turn to welded sandwich structures to obtain best possible strength-to-weight ratios. Maximum temperature that the welded structure can take is governed by the high-temperature characteristics of the metal from which it is made, instead of the bonding agent, such as in brazed honeycomb.

A unidirectional, cone-type of sandwich structure is now being made experimentally by Sciaky Bros., Inc., Chicago. Called "Trusscore," this all-resistance-welded structure is being developed



RESISTANCE WELDED SANDWICH
Low Cost May Spur Uses Outside Aircraft

specifically for aircraft use, but its relatively low cost – projected at $20 per sq. ft. in production – is expected to open other applications where up to now sandwich has not been economically attractive, although structurally advantageous.

Fabrication of the welded sandwich is accomplished in two operations. First, V-corrugations are joined to a facing sheet to form the half-panel assembly. This operation is accomplished by conventional seam welding techniques. Then, by a special resistance welding process, two half-panels are welded together at the corrugation nodes to form the finished sandwich panel.

This special node-welding process eliminates the need for internal electrodes at the point of welding, and makes it possible to manufacture a sandwich panel of almost any thickness.

Node welds are made simultaneously across the width of the panel, and at a rate of 3 ft. per min. along the length of the panel. This production rate is attained irrespective of panel width or length.

More Color for Metals . . . New Vistas for Designers

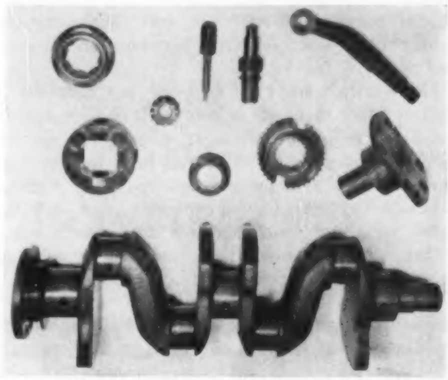
Production of colored stainless steel sheet and strip will begin this month. The product, called "ColorRold", is a development of Washington Steel Corp. and Stoner-Mudge Co., Div. of America Marietta Co. The color coating system employs a modified acrylic finish available in 11 standard colors. Washington Steel will offer colored stainless in all popular gages up to 60-in. wide. The coated product is readily formable and can be deep drawn without damaging the finish. (The new A.S.M. Headquarters has a stainless steel sunshade which is gold colored; it is the first architectural application of this color system.)

Aluminum sheet, up to 60 in. wide, coated with straight vinyl, vinyl-alkyd, and acrylic enamels is being produced by Aluminum Co. of America in 19 different shades. Called "Tone-Cote", the product is available as both a one-side or two-side coated sheet product. A different color may be applied to each side of the sheet. Alcoa says colored aluminum will be used to fill the expanding needs for color by manufacturers of such products as awnings, roofing and siding, mobile homes, garage doors, refrigerator cabinets, doors and other appliances, fence panels, and many other items.

Salt Bath Nitriding Process

An exhibit at the National Metal Exposition, in Chicago last Fall which attracted a lot of attention was Kolene Corp.'s presentation of a new salt bath nitriding treatment. Developed and proved in production in Germany, this process is being made available to American manufacturers by Kolene. Called "Tufftride", the process is applicable to practically all ferritic metals – low-carbon, alloy, stainless and heat resisting steels and various iron castings.

Although the process is a form of nitriding, no brittle white layer is formed. The increased fatigue properties and anti-galling characteristics of the surface are important to the design engineer. The surface produced is ductile, does not crack or spall and since there is no dimensional change, no stop-off is required for threads, keyways and sharp corners. Camshafts, crankshafts, cylinder heads (to prevent cracking), cylinder liners, oil pump gears, and steel stampings are among production-proved parts in Europe. The salt bath operation is carried out at about 1025° F. for soaking times of 90 to 120 min. The bath is composed of a



NITRIDED AUTOMOTIVE PARTS
Salt Bath Treatment
Improves Wear and Fatigue Resistance

proprietary salt containing cyanide as one of its components. Cyanide losses are only 1½ to 2% per 24 hr. of operation.

With the short time cycle, great output can be realized with small capital expenditure. Completely automatic furnaces can be used for processing mass-produced parts.

Yttrium Improves Oxidation Resistance

As an alloying element in certain heat resistant steels, yttrium (receiving attention for nuclear uses) provides substantial improvement in oxidation resistance at high temperatures. Research at G.E.'s Aircraft Nuclear Propulsion Dept. demonstrates, for instance, that when a small amount of yttrium is added to Type 446 stainless steel, the alloy has the same oxidation resistance at 2500° F. as the same grade without yttrium at 2000° F. It is also reported that 1% yttrium is equivalent to 5% aluminum in improving resistance to oxidation in iron-chromium alloys. Used together in such

alloys, the two metals give even better performance but create difficult fabrication problems. Studies also show that the rare metal helps prevent the entry of nitrogen and oxygen into the Cr-Fe alloys, thus improving ductility and impeding grain growth at high temperatures.

Materials Progress in Ceramics and Graphite

"The next 10 years will probably be known as the decade of materials research. We will see compressed into that 10-year period, what would normally require 50 years' research effort." This prediction was made by Charles N. Kimball, president of Midwest Research Institute, at the annual meeting of the Institute.

Continued Dr. Kimball: "The principal incentive to accelerating materials research is the fact that space flight – to which this nation is completely committed – forces us to meet new environmental conditions, such as very high vacuums, cosmic rays, ionized gases, acceleration, vibration and shock."

Dr. Kimball went on to point out that the impact of space research is being felt in industry, too, resulting in lighter, stronger metals, the development of materials to withstand high temperatures, new electronic systems and new coatings. Although developed primarily for missiles and satellites, many of these materials will find ready use in better, more economical products for industry and in a variety of every-day applications.

The great need for intensifying our knowledge of materials justifies a special effort to bring together the most recent findings of engineers and specialists working with metals and with other materials which are important to the metals engineer. Significant in this respect is a new class of high-temperature ceramics announced a few weeks ago. "Lucalox", as General Electric Co. calls the new polycrystalline ceramic which it developed, is closely related to sapphire and ruby gem stones, which are single-crystal aluminum oxide. But the polycrystalline form of aluminum oxide, characteristic of "Lucalox", is superior to these gems in its ability to withstand high temperature without deforming. Lucalox has a structure which is like metal in that its crystals are bonded directly to one another. Its light-transmitting ability is close to that of glass.

This new ceramic should extend the range of instruments and devices that are limited by physical characteristics of present materials, says J. Herbert Hollomon, manager of the General Electric Research Laboratory's metallurgy and ceramics research department. One example would be high-intensity incandescent and discharge lamps which are now limited by heat resistance of their transparent envelopes. (Lucalox is stable at temperatures close to 3600° F.) Another likely application is in the banks of infrared lamps which test the heat resistance of missile nose cones and other equipment for space vehicles. It may also be used as an electrical insulator and as a material for gem bearings in delicate equipment.

Another significant development in high-temperature materials is Raytheon's announcement of a process for making oriented graphite in commercial quantities. Because of its highly oriented crystal structure, this material, which the company calls "Pyrographite", offers a unique combination of high-temperature characteristics. Thermal and electrical conductivity is strongly anisotropic – higher (by several orders of magnitude) in a plane parallel to the surface than at right angles to it. Other valuable properties are high density and impermeability to gases.

Pyrographite is becoming an important material for rocket applications due to its high sublimation point, high strength and its anisotropic heat transfer properties. Of particular interest for applications in nuclear reactors is impermeability to gases. Using a standard mass spectrometer leak detector, no permeation by helium has been detected. The material exhibits this property after heating to 2500° C. (4500° F.) and recooling, even in films as thin as 1 or 2 mils.

From Here and There . . .

Almost pure Lithium-7 will be available for large-scale use in civilian reactors at $120 per kg., the A.E.C. announces. Li-7 has a low degree of neutron absorption, making it and its compounds useful as a coolant in nuclear reactors and as an additive to coolant water to prevent corrosion.

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Tubing of Zircaloy-2, in lengths of 51½ ft., is being extruded at Harvey Aluminum. Used in nuclear reactors, the tubing has a 3.58-in. outside diameter with a 0.360-in. wall. Billet weight is over 500 lb.

• • • •

Under contract with the Air Material Command, Crucible Steel Co. will work on a process for making columbium alloy sheets, 36 by 96 in. with uniform properties in the flat condition. Columbium melts at 4475° F. and promises the lightest structure of any engineering metal at the incandescent temperatures which will be encountered in future aircraft engines, airframes and missiles.

Are You Using Molecular Sieves?

Molecular sieves are taking on a prominent role in the metals industry. As a result of their affinity for polar compounds, these absorptive agents, made by driving off the water from crystalline sodium and calcium alumino-silicates, already figure in processes which depend on pure water-free gas or air. For example, they can pull moisture from hydrogen and drop its dew point from about 15° F. to −100° F. – an important point if you are heat treating parts in a hydrogen atmosphere. This is but one current application of molecular sieves which will be discussed in an article in next month's issue of *Metal Progress.*

Metal Progress
Vol. 77, No. 1 January 1960

Critical Points

By the EDITORS

Report on the Metric System

PERHAPS YOU WILL REMEMBER the "Critical Point" titled "Should We Go to the Metric System?" Published last August, it presented some pros and cons concerning the adoption of the metric system by this country, and asked for your opinions on what we should do. Well, letters from many of you have been received and the editors of *Metal Progress* are pleased to announce that the final tally was better than 15 to 1 in favor of adoption of the metric system. Such a result might have been expected, but it is gratifying to *know* that metals engineers are in truth the progressive group we have always felt they were. Actually, the average engineer's natural passion for simplicity and efficiency made this result a foregone conclusion.

It must be admitted that while practically all replies supported adoption of the metric system, there was sharp division as to the mechanics of changeover. Was it simpler to start at the school level, the industrial level, or both? Most were sure that there would be strong objections from industry because of the cost which was conceded to be in the billions. Despite this, they felt the change to be mandatory because of pressure from foreign competition. Today, in every part of the world, goods from the United States are competing with goods from other countries. Since the metric system is universal (with the exception of England and its dominions, which form a tight little marketing group of their own), foreign manufacturers start off with a built-in advantage. Their weights and measures system is easily understood by practically everybody they deal with, while ours (which even we concede to be more complicated and cumbersome) is beyond comprehension to most buyers overseas.

A quotation from one of the letters we received might indicate the problems faced by those who are not familiar with our archaic weights and measures system. Written by C. A. Liedholm of Curtiss-Wright Corp., this letter says, "Since I was brought up in that [metric] system, I am familiar with its convenience and logic. When I was 9 years old or so, all I had to remember was '. . . kilo denotes 1,000, hecto, 100, deci, tenths, centi, hundredths, and milli, thousandths'. With that and a few auxiliary items of information, I could convert any com-

mon unit into any other common unit. Today, I still have to look up such silly conversions as, 1 liquid gallon equals 231 cu.in. (in the United States, not in the United Kingdom), 1 cu.ft. (dry) equals 1728 cu.in., 1 United States gallon of water weighs 8.34 lb., and many others. I haven't met a single engineer yet who knows them all."

Remember, the foregoing is only one man's opinion – and he is a man who found he had to change over to the English system after he became an adult. Those who know only the metric system cannot help but gravitate toward products made and sold that way.

Yet, despite the advantages of the metric system, a change to its exclusive use would have a drastic effect on the whole economy. After all, practically everybody uses weights and measures constantly. To change every unit, name and all, would cause no end of confusion for quite a long time. Those readers of *Metal Progress* who replied had many suggestions for reducing this trouble to a minimum. For instance, most felt that it should be done over a long period, five to ten years at least.

Here is one idea: We quote Donald Hunter of the Martin Co., who says, "It [the metric system] could be brought into operation gradually, both systems being used for a time, with figures being given thus: 28.4 g. (1 oz.). This would emphasize the metric system and provide a guide as well."

A chemical engineer in Texas, Stephan J. Stolton, suggested a similar gradual approach, and added a novel changeover-by-area method. Here's how it goes. At first, milk could still be bought in quarts, but these would be "0.95 liter" bottles. As bottle-making machines wore out, they would be replaced by machines which made liter bottles. Then, the remaining quart bottles would be moved to another area, and the new liter bottles would take their place. As time went on, more liter bottles would appear while the quart bottles disappeared. Gradually, area by area, the change would go on until the country was metric as far as milk was concerned. (To be consistent, gallons, pints, and half-pints should be changed along with quarts, though Mr. Stolton didn't mention this.)

So much for that. Suggestions as to how changeover could be accomplished are perhaps best summed up in Mr. Goering's letter printed in the correspondence section of this issue. (Other letters on this subject are also in the correspondence department, p. 134.) Basically, he proposes that the change be made at a nonindustrial level – children would be taught the metric system from the start, the Government would use the metric system in all of its activities, and the like. In time, industry would change to accommodate to the new conditions.

Unfortunately, the picture as drawn by our correspondents is not complete. Though there is wide agreement that the change should be made, nobody seems to have any idea of the cost. Actually, this is not surprising. There are no figures. Some research showed us that American manufacturers long ago decided the change was too expensive, and now take the attitude that "Since we are not going to change our weights and measures system anyway, why should we spend money trying to figure out the actual cost? We already know it costs too much, and that's all we need to know."

There is some reason in their belief. We all know that our manufacturers are extremely cost-conscious. They are well aware, as we mentioned before, that foreign competition presses at them from all sides. All of them know that the metric system is much easier to use than the English system. If our manufacturers thought for one minute that the metric system would save them money, they would start using it tomorrow. As it is, however, the system is seldom discussed in industrial circles. Apparently, our industrialists have given up on it as a cost-cutter despite its potential.

So we reach an impasse. Scientists and laboratory workers already quite uniformly use the metric system and they can talk to foreign counterparts without misunderstanding. The electrical and electronics industries, born comparatively recently, are based on metric units (although an outlet plug bought in New York will do you no good in Paris). It seems to the editors of *Metal Progress* that any American industry or firm with any aspiration to do business outside of the United States should carefully assess the advantages of the metric system of measurement as applied to their product and weigh the cost against the expected profit of a change to a new measurement system. Here is where the metals and materials engineers can exercise some influence.

If you believe that the metric system is superior to the one we use today and that its ultimate adoption is certain, analyze the facts and then try your best to convince your management. That is the only way it will ever come about in free America.

An English Metallurgist Looks at . . .

Progress in Metal Forming

*By D. V. WILSON**

In this review of forming practices here and in Europe, the author suggests several areas where the metallurgist can make valuable contributions. These include the development of new cold drawing alloys, and methods for processing familiar alloys. (G4, G5, G9, G14)

PERHAPS THE MOST SIGNIFICANT recent advances in industrial cold forming have been in the development of mechanical equipment. For example, transfer presses are now in use which carry out many separate operations with automatic transfer from one stage to the next. Figure 1 illustrates typical parts made by these processes. Such machines may produce 1000 components per hr. with an output per operator 20 to 40 times as high as that achieved with single-stage presses. From the automatic press, it is but a step to the automatic press line, and, beyond this, to the automatic factory.

Another cold forming technique with very high output rates is cold extrusion. Its outstanding characteristic: Extremely large deformations can be carried out in a single operation. Now established as a method of forming some of the stronger metals including steel (Fig. 2), it can provide outstanding economies when applied to properly designed components.

The newer industries have created new problems in metal forming. The exacting service conditions required by aircraft and rockets, for example, may require materials which would certainly not be chosen for their forming properties alone. Also, pressings of great size or complexity are often needed to reduce the number of separate components in the final assembly. The builder may need only a few parts of a given design; this alters the economics of the process. These unusual requirements have been answered by such special techniques as rubber pressing, "marforming", "hydroforming", roll forming, and explosive forming.

These advances in technique have been aided

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Fig. 1 – Production Stages of Sheet Metal Components Produced on Transfer Presses. Output can exceed 1000 pieces per hr. (From L. Schuler A.G., Germany)

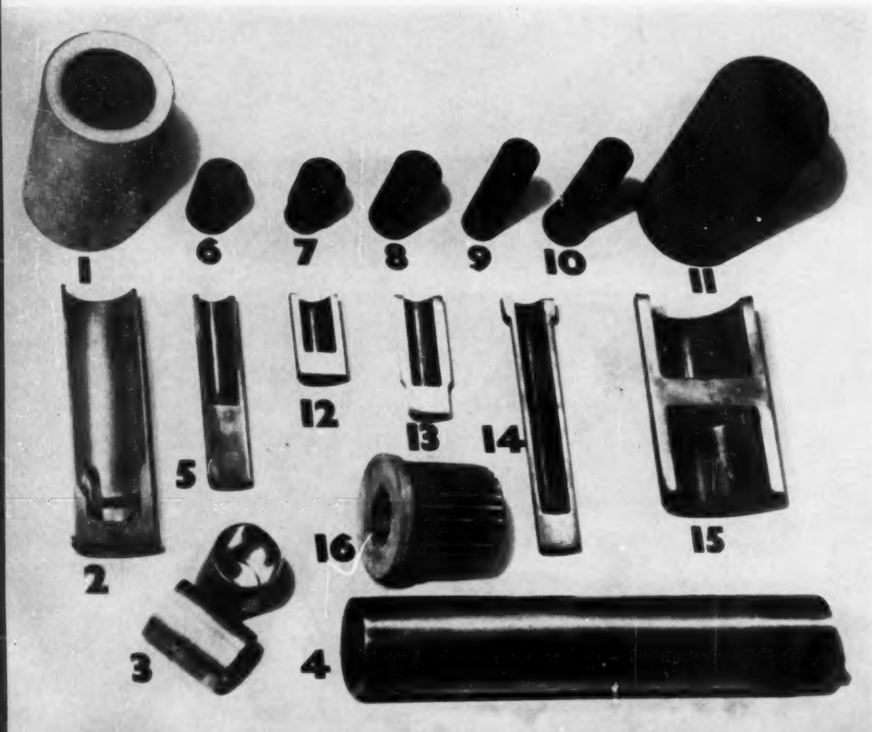


Fig. 2 – Examples of Cold Extrusions Manufactured at R.O.F. Birtley, England. Numbers 1 to 4 are backward extrusions in aluminum and aluminum alloys (14 S and 75 S) with reductions of 50 to 80%. Number 5 is a backward extrusion in 70-30 brass. Numbers 6 to 16 are low-carbon and mild steel components

by progress in materials. Continuing developments in refining, casting and rolling have all played their part in providing new materials, and in improving the economy of production and the quality of established alloys.

Despite this progress, it is the engineer, rather than the metallurgist, who has pioneered the outstanding recent advances in metal forming. Generally, developments concerned with modes of deformation, tool configurations and frictional conditions appear to offer more scope for improving performance than do attainable improvements in materials. In deep drawing, for example, performance is known to be rather insensitive to moderate variations in plastic properties. In drawing flat-bottomed cylindrical cups from low-carbon steels, aluminum, brass and copper, in conditions varying from fully annealed to half-hard, typical test results for all these materials are found to lie within the range of drawing ratios 2.0 to 2.2. This may be contrasted with the changes in drawing performance resulting from seemingly trivial variations in drawing conditions. Figure 3 summarizes tests showing that, in drawing rimming steel, the drawing ratio can be changed from about 2.30 to 2.20 by a less than tenfold increase in drawing speed. At the higher speed, the drawing ratio can be improved from 2.20 to 2.45 simply by removing the lubricant from the punch side of the blank.

Forming Limits

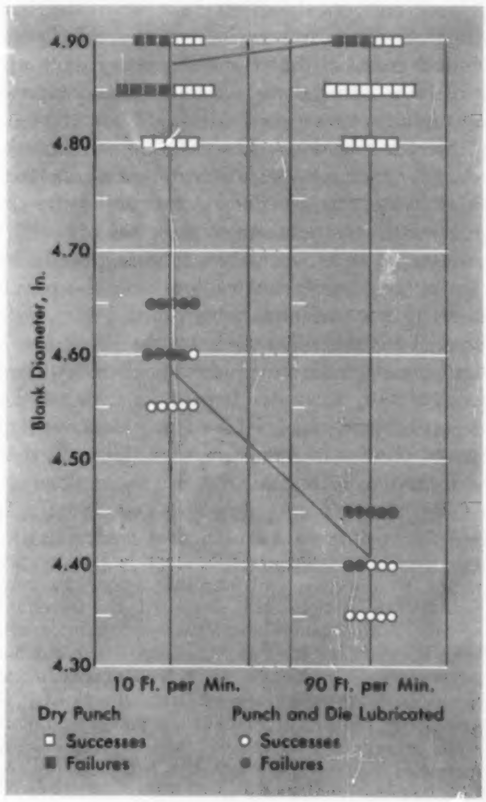
What are the fundamental factors limiting the cold deformation which may be applied to a metal in a particular operation? A useful insight is provided by analyses of the stress-strain systems operating in different types of metalworking processes.

Deep Drawing — In deep drawing, for example, the sensitivity of the drawing ratio to variations in lubrication and tool form, and its relative insensitivity to the plastic properties of the metal, can be interpreted in terms of the following analysis.

As Fig. 4 shows, in drawing a cup from a flat blank, the systems of straining are basically different between the outer region of the blank (which is initially held between die and blank holder) and the central region over the punch head.

When fracture occurs in cup drawing, it generally does so in the metal which is thinned by stretch forming over the punch profile radius. Thus, with material of given plastic properties and thickness, the load at which fracture occurs is largely determined by conditions within the stretch formed zone, such as punch profile, and the restraints due to friction. However, the load this region is called upon to support is determined by events in the outer drawing zone. Blank diameter and the frictional drag imposed by die and pressure plate are most important. A decrease in friction or in the metal's yield strength affecting only the stretch formed zone will decrease the load which can be supported and so reduce drawing capacity, but similar decreases affecting only the drawing zone are beneficial. An over-all change in the metal's strength or in lubrication will generally act to change both the drawing load and the fracture load in the same direction. In this event, the resultant change in

Fig. 3 — Deep Drawing Tests Made at Two Speeds on an Annealed Rimming Steel With a Hemispherically Nosed Punch, 2 In. Diameter. An E.P. oil lubricant was used. For the upper results, oil was on the die side of the blanks only. Oil covered both sides of the blanks for lower results. See text for explanation of results



drawing capacity will reflect only the difference of the changes in drawing load and fracture load. On the other hand, the benefits of differential lubrication* illustrated in Fig. 3 can be explained as a consequence of increasing punch-side friction. An increased load can be supported without any corresponding change in the drawing load.

We might note that the superior drawing performances obtained with the marforming and hydroforming techniques must often occur because the stretch-formed zone is clamped rather firmly to the punch by the pressure exerted on the outer surface of the component. At the same time, friction on the "die" radius (but not on the pressure plate) is practically eliminated.

This view of the deep drawing mechanism also explains the outstanding results which can be achieved by differential annealing or differential heating of the blank during drawing. In both instances, material in the drawing zone is softened in relation to the material in the central stretch formed zone.

Failure in deep drawing is, essentially, failure to support the drawing load. Large deformations are practicable if they are subdivided into separate draws, to keep loads within safe limits. It is significant that transfer presses have appreciably reduced the economic disadvantages of multiple operations.

Stretch Forming – The criterion of failure in stretch forming is essentially different from that in drawing. In true deep drawing, the stretching of the material over the punch head is inessential in the operation. The deepest draws are obtained when metal flow over the punch head is most effectively restricted. In a pure stretch forming operation, on the other hand, *uniform* stretching over the punch is required and a high work hardening capacity in the metal is clearly beneficial. Once local necking starts, the material must be annealed if further deformation is required.

*With liquid lubricants, the influence of drawing speed on performance is often due, predominantly, to effects of differential lubrication. Lubricity seems to improve with drawing speed because fluid-film conditions are promoted by increased speed. With a general improvement in lubrication, both the drawing load and the load which can be supported are reduced. In a free draw with a hemispherically nosed punch, the effects of improved punch-side lubrication are generally dominant, and drawing capacity then decreases with increased drawing speed. With a flat-nosed punch, the opposite is generally true.

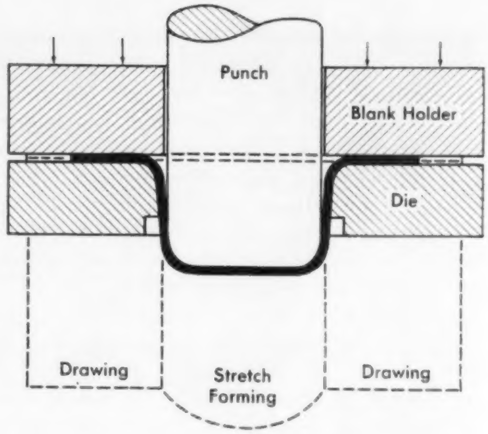


Fig. 4 – Systems of Straining in Deep Drawing

In practice, tool form and lubrication are also important, and they greatly complicate the prediction of performance. In one experiment, identical sheets were stretch formed at three different speeds, using a liquid lubricant on a hemispherically nosed punch. Result: Lubrication improved as punch speed rose. When frictional restraints are reduced, the applied biaxial stress system increases general thinning of the metal before plastic instability and local failure develop. Improved punch lubrication thus acts to improve stretch forming performance.

It is evident that performance in those explosive forming operations which are essentially stretch forming will be favored by completely eliminating punch friction. In other instances, the high compressive stresses produced by explosives may be used advantageously.

Extrusion – In considering high deformations, the most intriguing results are those achieved by a single cold extrusion. Although volumetric stresses apparently do not affect yielding behavior, they have a pronounced effect on fracture. Tension promotes it. Compression suppresses it. For example, in his classic researches on the effects of pressure, Bridgman showed that reduction in area at fracture of a 0.45% carbon steel test piece can be increased to 90% by applying a surrounding pressure of 16,000 atmospheres. This is comparable to tool loads experienced in cold extrusion of steel.

Scientific Design in Metal Forming

A discussion of the factors which control forming limits must give first place to the underlying importance of the applied stress system. In the light of this, one may question what

further contributions the metallurgist can make to the development of metal forming. In fact, it was recently suggested that future advances depend principally on the tool designer, while the metallurgist can make only marginal improvements in the quality of materials. This judgment overlooks a number of potential developments in materials, in particular the increasing demand for materials that are "tailor-made" to suit the combined requirements of the appropriate forming methods and service conditions. Wherever metals must be used with maximum efficiency, such as in aircraft and nuclear engineering, this requirement is obvious. However, the same trend is evident among materials used in mass production.

Measuring Formability

The scientific design of materials demands a good understanding of the relationships between initial properties, behavior in forming, and final properties.

In practice, predicting a material's performance in a forming operation remains something of an art. Process development is evolutionary, and in the last stages still owes much to cut-and-try methods. In stretching and drawing operations at least, there is still no way to calculate forming limits from basic properties with useful precision.

However, progress would be slow indeed if it relied solely on the crude "go, no-go" gage of success or failure in practical operations. In fact, research has established laboratory tests for drawing and stretching properties which are quantitative, and can produce a measure of formability which is considerably more discriminating than can be derived from uniaxial tensile tests.

Surprisingly, the metal forming industries have not benefited much from quantitative deep drawing tests. This is probably because such tests depend for their success on simulating actual forming conditions. To be sufficiently accurate, they must be sufficiently simulative. Most of the disappointments are probably due to attempts to apply these tests in inappropriate conditions.

It is difficult to analyze practical metalworking operations. In the first stage, it is probably best to compare the performance of known materials both in laboratory tests and under a wide range of conditions met in practice. This important step is now being actively promoted by such organizations as the International Deep Drawing Research Group and the Institute of Sheet Metal Engineering, and the results will provide an important stimulus to improvements in material selection and development.

Matching materials to the forming operation is only half the problem, however. Improvements in the properties of the formed product are also to be considered. To illustrate, let us discuss one aspect of possible improvement – namely, designing for mechanical strength.

Designing for Strength

The mechanical properties of a manufactured component depend on the forming operation as well as on the basic properties of the material. Despite this, there are few materials available which have been developed specifically to exploit the potentialities of cold working as an economical method of obtaining high strength.

The aluminum-magnesium alloy series are an example of such materials. With good stretching and drawing properties, they can develop relatively high strength through deformation. Within limits, the mechanical properties of the final product can be matched to service requirements by using the proper magnesium content.

Work Hardening Capacity

A high work hardening capacity not only leads to greater final strength but also can improve formability in drawing and stretching operations. Work hardening is structure sensitive and can be controlled through composition and microstructure. Even in single-phase materials, simultaneous improvements in strength and formability are claimed for materials having the very fine grain sizes produced by modern short-cycle continuous annealing.

In the future, materials of extra high work hardening capacity may be devised especially for cold forming where high strength, rather than ductility, is required. Such materials would perform particularly well in stretching if work hardening were sustained through a wide range of deformation. Intrinsic work hardening might be enhanced by arranging for a phase transformation to occur as a result of deformation, or by rapid strain aging in some substitutional alloys. Indeed, some austenitic stainless steels evidently owe part of their high work hardening capacity to a partial transformation to ferrite during working. Stress-induced transformations in some beta titanium alloys appear to offer similar opportunities for enhanced work hardening.

Austenitic steels illustrate both the advan-

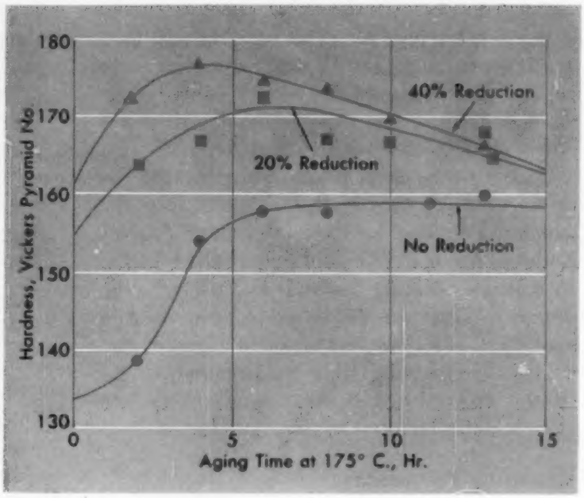


Fig 5 – Effect of Previous Cold Work on Aging Behavior of Duralumin

tages and disadvantages of high work hardening capacity. They have excellent stretch forming characteristics, and can develop useful strengths of about 180,000 psi. Disadvantages include high tool loads, lubrication difficulties and excessive spring back. However, cold extrusions are now made successfully with oxalate coatings. Some explosive forming techniques appear particularly promising for this type of material. The large forces required present little difficulty, and lubrication and spring back problems can be greatly reduced.

Generally, the unexplored territory of explosive forming particularly intrigues the metallurgist. Even conventional materials can be expected to behave in novel ways and give unusual properties, due to alterations in the modes of deformation and the production of new types of microstructure.

Whatever the mode of deformation, it is probably safe to say that the highest useful strengths will be produced by cold working alloys which contain fine precipitates. Piano wire, conventionally drawn, can be as high as 400,000 psi. This is by no means the theoretical limit. Bridgman* drew piano wire with a superimposed hydrostatic pressure of 180,000 psi. to an astonishing 580,000 psi. while retaining over 20% reduction in area. Current research both in the West and in Russia on the effects of hydrostatic pressure in forming, and on extrusion using direct hydraulic pressure, may lead to new industrial processes. However, probably the most important contribution the metallurgist can make in this field at present is to provide reliable tool materials of exceptional strength. Recent developments in cermets could be useful here.

Wider advantage could be taken of the materials which can be formed in the solution heat treated condition and then age hardened. Thus full strength is developed after forming is complete. In this way, finished components of high strength can be produced without the need for high tool loads. Existing age hardening alloys vary widely in their suitability for this type of operation, and much remains to be discovered about the interrelations of plastic deformation and precipitation. Generally speaking, however, increased nucleation on dislocations can be expected. In some alloy systems, precipitation will cause more rapid and more effective hardening. In substitutional systems, cold working enhances diffusion rates to promote both precipitation and overaging. Figure 5 shows how previous cold working affects aging of a commercial duralumin. In drawn components, this type of behavior can be turned to good account, since it provides some degree of choice of the final strength distribution independently of the cold work distribution imposed by the forming operation. Short aging periods develop strengths up to 90,000 psi. in the more heavily deformed regions, while the lightly deformed material remains less strong. Longer aging periods will give much more uniform strength with some reduction in the peak strength values.

At present, most of the materials to which this type of strengthening technique can be applied are conventional age hardening alloys designed for hardening by heat treatment alone. There can be little doubt that many alloys specifically designed for hardening by a combination of cold working and precipitation hardening remain to be developed.

Far from being relegated to the task of making marginal improvements in existing materials, metallurgy can make an increasingly important contribution to progress in metal forming.

*As described in discussion of Technical Publication No. 2449, *Metals Technology*, Vol. 15, 1948, p. 102.

Report From Switzerland

Steel Castings for High Duty

*By HANS E. HÜBSCHER**

Brief description of equipment installed at a leading Swiss foundry and the manufacturing and control methods for making steel castings for especially severe services. (E-general, 1-52; ST, AY)

SINCE TIME IMMEMORIAL, metal castings have produced intricate and useful shapes, reaching this pre-eminent position long before cutters were available to machine equivalent shapes out of more massive pieces. Traditionally, the more fusible metals like lead, copper alloys and cast iron were used, and about 75 years elapsed after ingots were cast from crucible steel before small, high-carbon steel castings were made by F. H. W. Needham in England, and a century before low-carbon steel castings were made commercially by J. C. Fischer in Switzerland (1840). The difficulties in handling this strong, refractory metal and its alloys were surmounted slowly and with difficulty. Nevertheless, with the aid of advanced metallurgical techniques and close quality control, steel castings are now made which have uniform properties in all directions. By virtue of alloying and heat treatment, these properties can include tensile strengths as high as 190,000 psi. and excellent resistance to cavitation and to corrosion by various chemicals.

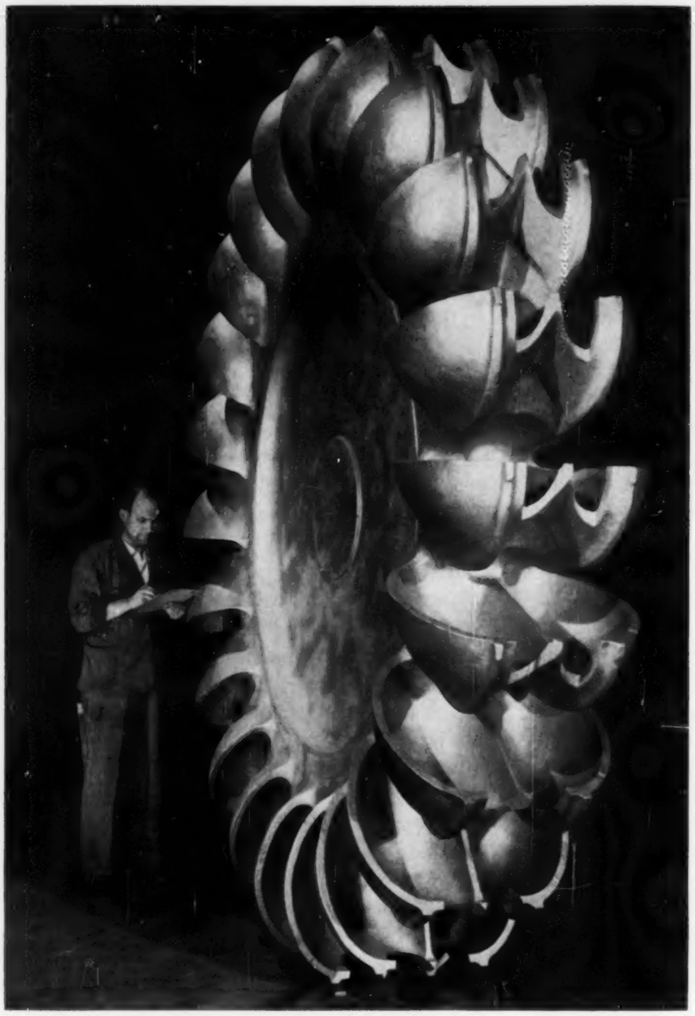
In the following notes an attempt is made to give an account of the manufacturing, inspecting and machining methods at the steel foundry of George Fischer Limited at Schaffhausen, Switzerland, one branch of a large jobbing foundry. The main production is steel castings for hydraulic, steam and gas turbines, electric generators, large diesel engines and aircraft. Runners for water turbines are almost a specialty. Castings have been shipped weighing up to 45 tons. As a rule, the castings are delivered rough machined, with a small finish-machining allowance.

Melting – The melting shop has four basic-lined electric arc furnaces ranging from 8 to 30 tons capacity. All have a swinging roof for top charging and the 30-ton furnace is equipped with an A.S.E.A. magnetic stirring device.† Proper stirring is necessary to expedite the reactions between slag and molten steel and also for evenly distributing the alloying additions. Since really good stirring of large heats by hand is a difficult and slow operation, almost impossible to do properly, a magnetic device is of great help and is applied successfully.

Induction furnaces with capacities from 1000 to 3000 lb. are available to make smaller castings, especially in high-alloy steels with low carbon.

*Chief Metallurgist and Metallurgical Advisor to Manager, George Fischer Steel Foundries, Schaffhausen, Switzerland.

†Manufactured by the Swedish General Electric Co. (Allmänna Svenska Elektriska Aktiebolag, or A.S.E.A.). It consists of a coil fixed underneath the furnace shell and through which flows an alternating current of very low frequency, roughly one cycle per second. The circulation of the molten steel is reversible in direction. (The bottom part of the furnace shell is made of nonmagnetic steel plate.) This stirring device is used in the United States by General Electric Co., Republic Steel Corp., and Timken Roller Bearing Co.



Pelton Water Wheel Runner for a 130,000-Hp. Water Turbine. 13% chromium steel; diameter 11 ft.; weight 12 tons

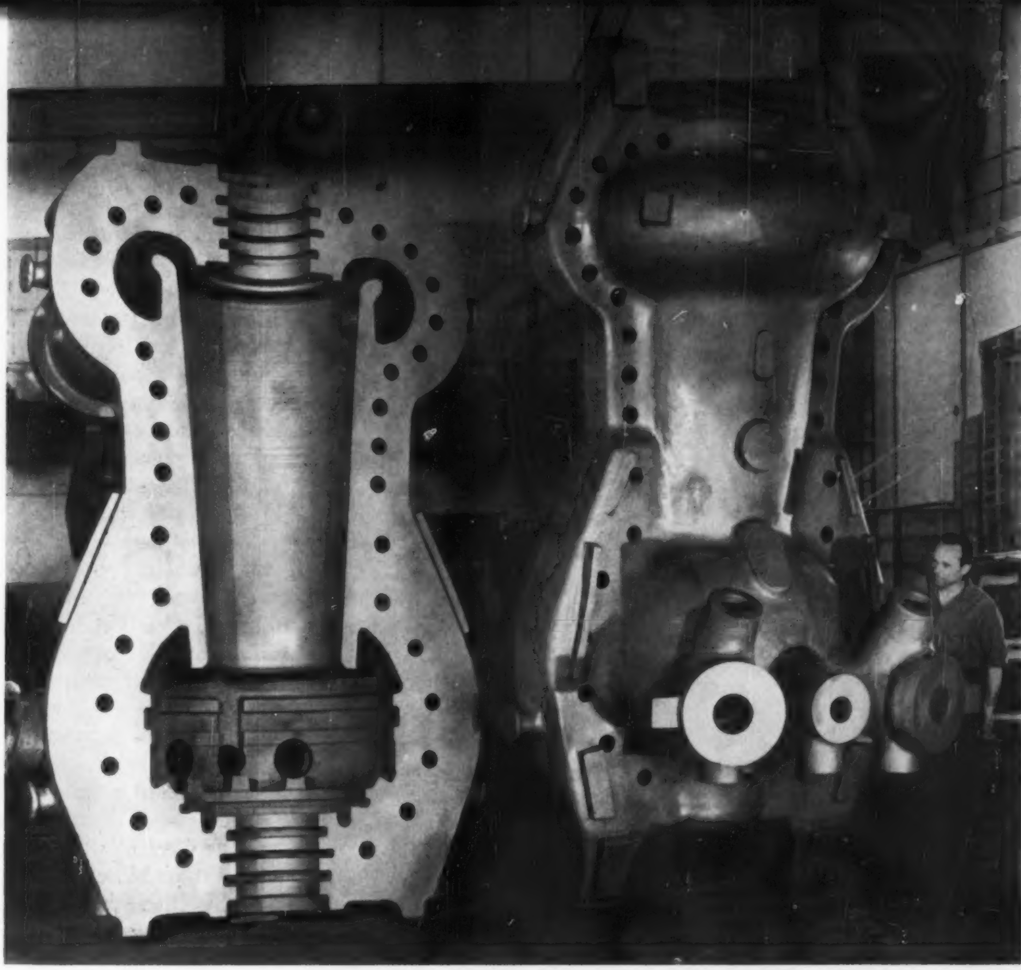
Steel has been melted in electric arc furnaces at Fischer's for over 50 years and it is now more than 10 years since oxygen lancing was introduced. Originally this was confined to heats remelting stainless steel scrap, but now every heat is melted with the help of oxygen. In principle, the refining practice has remained the same in the course of years, operating with two slags.

The temperature of the liquid steel is measured with immersion pyrometers in the furnace and also in the ladle at the pouring stations. Chemical compositions are checked during the heat by rapid analytical methods. Quick methods have also been developed in a special laboratory for gas analysis.

Molding – The molds for the medium size and the large castings are made of chamotte*, while the molds for small castings consist of a mixture of natural molding sands. All molds are dried with the aid of portable driers which blow hot air through them, the air being heated either by gas or electricity. Large cores are also made of chamotte. Cement-sand molding was tried experimentally for a time, but abandoned on account of lack of space for air-drying the molds and because of higher costs.

Heat treating furnaces are all fired with producer gas from our firm's gas works. Large tanks are ready for oil and for water quenching.

*Chamotte is a synthetic molding material made from calcined aluminous clay, ground and sized, and mixed with about 10% raw clay and an appropriate amount of water.



High-Pressure Steam Turbine Casing of Cr-Mo-V-W Steel; Weight 20 Tons

Cleaning – In the last few years, the practice of smooth grinding of the outside, unmachined surface of steam turbine casings, pump casings, and similar high-duty castings has been greatly extended, since it facilitates nondestructive testing.

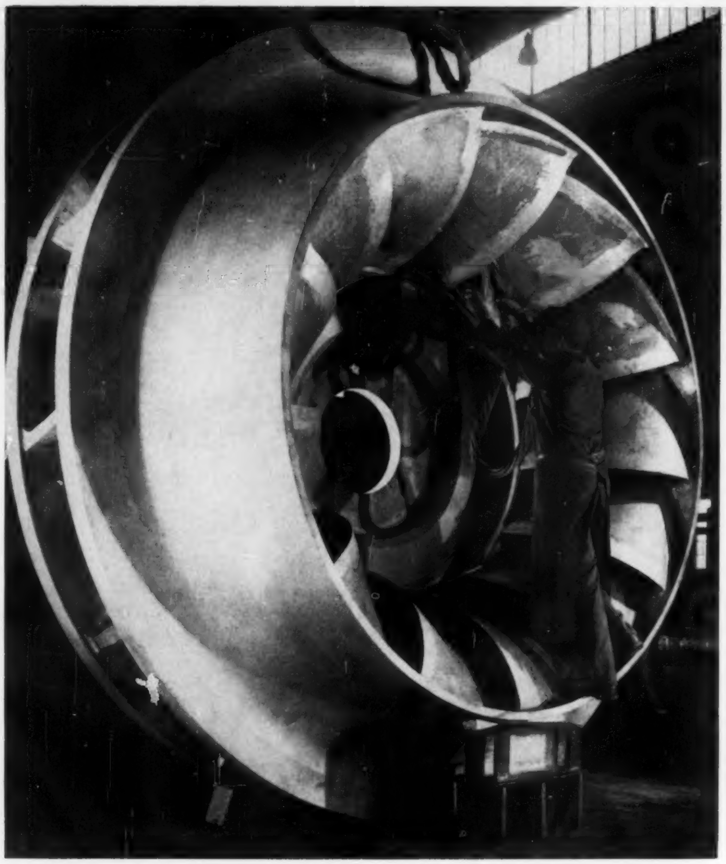
Machining – As mentioned before, practically all our steel castings are delivered rough machined with a certain allowance for finish by the customer. (This, of course, gives a close dimensional check and layout of the casting.) On a few occasions we have finish machined and polished water turbine runners. It is possible that this trend toward completely finished water turbine runners will be extended. As a matter of fact, the Fischer steel foundry is equipped with all the necessary machine tools for machining even the largest of our castings. For example, the biggest vertical boring mill can machine a casting up to 26 ft. in diameter.

Welding was originally merely a means for repairing foundry defects. It has also often become a part of manufacturing. I refer to such things as welding connecting pieces on steam turbine casings, welding tubes on pump casings, welding nozzle boxes into steam turbine casings. These welded connections are replacing bolted flange connections on high-pressure steam turbine casings.

All such joints are made by arc welding. Extensive facilities are available for preheating prior to welding, as well as for post-heat treatments. Preheating is of course most important for alloy steel castings of high hardenability in order to avoid cracks at and alongside the joints. Special mention should be made of a device for preheating by electrically induced currents.*

Inspection – Besides chemical analyses and determinations of mechanical properties, extensive use is made of nondestructive testing,

*See "Induction Heating for Stress-Relieving Large Steel Cylinders", by G. W. Seulen, *Metal Progress*, January 1957, p. 126.



High-Head Runner for a 175,000-Hp. Francis Water Turbine. 13% chromium steel; diameter 12 ft.; weight 23 tons

particularly the following methods: Magnaflux, ultrasonics, X-rays, gamma rays, betatron, dye check (and sometimes acid pickling). All important castings, such as those for hydraulic stations or steam power plants, are inspected by Magnaflux or ultrasonic rays during manufacture and finally by radiography.

For the last-mentioned, a 250-kv. X-ray set and radioactive sources of cobalt-60, cesium-137 and radium are available, but the instrument now most widely used is a Brown Boveri betatron of 31 Mev. This has been in regular operation since 1957 after a trial period of nearly two years. With it castings with a wall thickness up to 20 in. can be radiographed. This is the first betatron to be used industrially on the European continent and is believed to be the only one in a foundry in Europe. It is now housed in its own building made with thick concrete walls having barite aggregate. One great advantage of the betatron is that it has short exposure time as compared with that necessary for X-rays or radioactive isotopes.

The amount of work spent on cleaning, controlling and testing of steel castings has been growing steadily as a result of the more rigorous specifications written by our customers.

Laboratories — Besides carrying out analyses by wet methods and physical-chemical methods, the chemical laboratory makes much use of the spectrograph. Our equipment includes a Zeiss quartz spectrograph, a French direct reading spectrometer ("Spectro-Lecteur") and a quantometer made by Applied Research Laboratories, the latter being employed primarily for checking the chemical composition of the steel during the refining process.

A few years ago a gas laboratory was built to study the influence of gases in the steel upon the properties of the castings. Equipment is designed for quick estimation of hydrogen, nitrogen and oxygen in the steel during the melting process. The gas laboratory also has a vacuum melting unit for research work.

Our physical and metallurgical laboratory is continually working on new alloys and better heat treatment methods, as well as testing the mechanical and magnetic properties of the different steel grades under various conditions. Small melting furnaces and heat treating furnaces are at the disposal of the technologists. More and more emphasis is being placed on fatigue tests, impact tests at subzero temperatures and particularly creep tests at elevated temperatures. On several occasions, endurance limits have even been specified as acceptance tests for water turbine runner castings. Impact tests at low temperatures using Schnadt test pieces (special V-notch test pieces) are made principally on steels for ordnance castings. Because of the extended duration of creep tests, the number of machines for creep tests had to be increased and this subdivision of the laboratory now has equipment for 300 test bars *in toto*.

The task of our central sand laboratory involves research as well as the testing of molding sands and refractory materials.

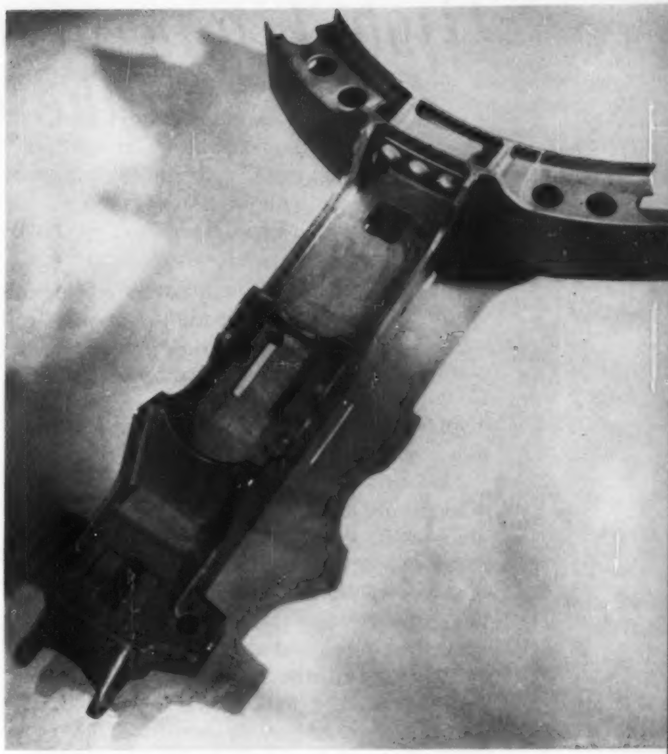
All these laboratories are now housed in a a new building. Although they work chiefly for the steel foundry, they also do the routine work for the malleable iron, gray iron and light alloy foundries of the Fischer company.

Cast Steel Grades – The steel foundry of George Fischer Limited makes castings in over 70 analyses of steel, including corrosion resisting, heat resisting, creep resisting and wear resisting steels. Corrosion resisting and creep resisting steels have now been cast for more than 30 years.

Low-alloy steel castings are manufactured with a large range of tensile strengths, up to 190,000 psi. Castings for aircraft are mainly for parts of the landing gear, most of them made of chromium-molybdenum steel (1% Cr, 0.3% Mo) heat treated for tensile strengths in the range of 100,000 to 175,000 psi., according to specification. Experience has shown that besides correct heat treatment the sulphur content of low-alloy high-tensile steels must be *very* low in order to meet severe specifications – less than 0.01%.

Many years of experience in the manufacture of intricate steel castings, and possession of the necessary modern equipment, particularly for nondestructive testing, place Fischer in a position to supply castings complying with all specifications for atomic power plants.

To supply corrosion resisting castings suitable for the many different applications in industry, we have added some nickel-base alloys to the group loosely called "stainless steels". Cooperation with customers in the field of corrosion resisting alloys has led to a satisfactory solution in nearly every instance.



Aircraft Casting of Chromium-Molybdenum Steel. Tensile strength is 128,000 psi. min., weight 135 lb., 100% radiographed

One interesting feature is the growing use of the 12 to 13% chromium steel for water turbine castings. Repairing any damage from cavitation or erosion is no more a problem (now that correct welding techniques have been devised) as has been demonstrated on many occasions.

It would certainly be of advantage if the number of steel grades could be reduced. Especially in the field of creep resisting steels there are too many varieties with practically the same properties. The same thing applies to the heat resisting steels. The only domain where a reduction of the number of steel grades is hardly possible is that of the corrosion resisting steels, since there are a great many different conditions of service, and many analyses have been devised to meet particular conditions.

High-Temperature Alloys in the U.S.S.R.

By A. G. GUY*

Soviet research covers a wide range of topics having a bearing on high-temperature strength and plastic deformation. Close cooperation is maintained between research and industrial plants for rapid application of scientific advances. (Q-general, M24, 2-61; SGA-h)

Lenin Prospect is a wide, attractive boulevard in a new section of Moscow along which official delegations often make their triumphant entry to the city. The traffic bands are separated by lawns planted with shrubs and flowers, and often there are colorful banners and posters lining the boulevard. The name "Avenue of the Institutes" is sometimes given to Lenin Prospect because several research institutions are imposingly situated on block-long grounds along the boulevard.

One of these is the Institute of Metallurgy of the Academy of Sciences of the U.S.S.R. named for A. A. Baikov – considered to be the most important metallurgical research institute in the Soviet Union. Its 30 research groups or laboratories are led by many of the country's best known metallurgists – I. I. Kornilov, I. A. Oding, and I. M. Pavlov are featured in this article.

The field of high-temperature alloys is an important one at the Institute and serves as a good example of research procedures there. An important point is the degree to which the work is divided among several groups. For example, special vacuum melting is done in the laboratory of A. M. Samarin, difficult plastic deformation by Pavlov's group, the majority of testing by Oding's group, and research on alloy compositions by Kornilov's group. Although each group carries out its own investigations relatively independently, there is effective cooperation when a topic requires the capabilities of two or more groups.

It is largely because of the division of effort that a wide range of topics is being studied having a bearing on high-temperature strength. These include: dislocations, electronic structure, atomic displacements, bonding forces, and alloying principles, as well as various properties of many rare metals. A surprising gap in this coverage – the absence of any evidence of programs of alloy development – can perhaps be explained by the reluctance of the Soviets to reveal compositions of new alloys. A commendable feature of Soviet research is the close cooperation between industry and research institutes.

Laboratory of Chemistry of Metallic Alloys

This laboratory, under the direction of Prof. I. I. Kornilov, is best known for work on alloying behavior, along the general lines of the Hume-Rothery rules. Present experimental work includes the determination of binary, ternary and more complex equilibrium diagrams of metals such as iron, nickel, chromium, tungsten, molybdenum, titanium and columbium. Intermetallic compounds are considered from several viewpoints: alloying behavior, thermodynamic properties, and creep properties.

Phase relations in many component systems, a topic of great importance for high-temperature alloys, are receiving much attention. Kornilov's work has indicated that actual phase

*Professor of Metallurgical Engineering, Purdue University, Lafayette, Ind. Dr. Guy was on leave at the Baikov Institute of Metallurgy in Moscow, January to July 1959. Acknowledgment is gratefully made by the author to the National Science Foundation for the grant under which this study was conducted and to Purdue University for a sabbatical leave.

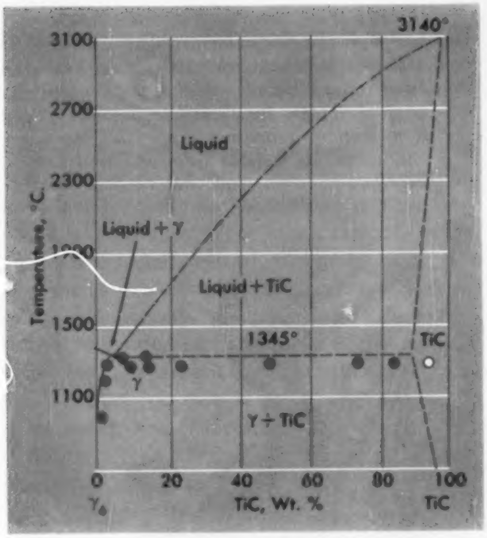


Fig. 1 – Constitution Diagram of the Quasi-Binary System TiC and γ_6 Which Designates a Six-Component Solid Solution

relations may be much simpler than the most general cases possible under the phase rule. The simplification is possible because of the great tendency toward the formation of both metallic solid solutions and metallidic solid solutions. The latter is a solid solution between intermetallic phases – for example, between Ni_3Cb and Ni_3Ta.

When only a metallic solid solution forms from the liquid phase, as in a limited portion of the six-component system, Ni-Cr-W-Mo-Cb-Ti, the phase constitution can be represented almost as in a binary system using only a liquidus line and a solidus line in a temperature-composition section through the diagram. If a metallidic solid solution also forms from the liquid phase, the phase constitution may be represented by a similar but somewhat more complex temperature-composition section. Triangular sections would be adequate for the representation of isothermal relations among three phases, and tetrahedral space figures for four phases.

An application of some of these ideas was made in an experimental study of the equilibrium between TiC and the solid solution containing 82% Ni, 7% Cr, 3% W, 3% Mo, 3% Al, and 2% Cb. By considering the system to be composed of only two phases, TiC and the six-component solid solution, the constitution diagram was treated as a quasi-binary section and was found to have the simple eutectic character shown in Fig. 1.

Diffusion and High-Temperature Strength

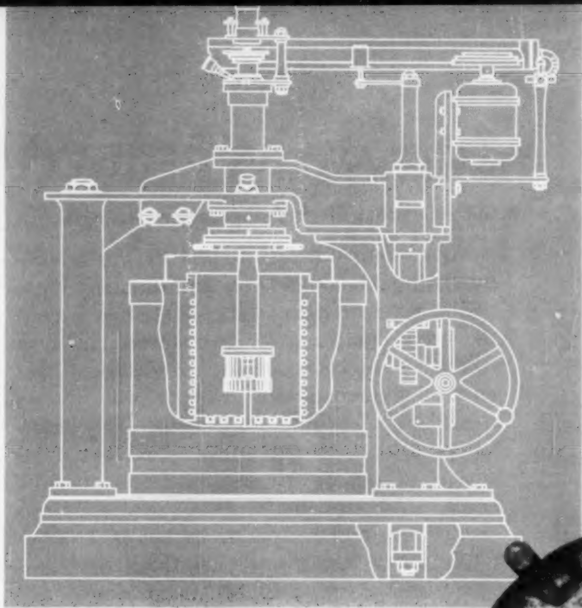
Another topic being studied by this laboratory is the relation between diffusion and high-temperature strength. When these two properties were compared for two, three, and five-component nickel-base alloys, it was found that good high-temperature strength was accompanied by a low rate of diffusion. This observation is consistent with the view that diffusion processes are the basis of deformation by creep. Although the five-component alloy was the strongest at temperatures below 1100° C. (2010° F.), it became weaker than the three-component alloy at higher temperatures and its diffusion rate became greater.

A more detailed study of the interrelation of composition and temperature with high-temperature strength and diffusion was made on a five-component nickel-base alloy containing 20% Cr, 6% W, 4.5% Al, and 0 to 9% Ti. It was found that the titanium content at which the diffusion rate was a minimum shifted from 3% at 955° C. (1750° F.) to 0.5% at 1250° C. (2280° F.), in agreement with the corresponding shift for maximum high-temperature strength.

The data on high-temperature strength discussed above were obtained by the centrifugal method.* The essence of the method is shown in Fig. 2. When the assembly is spun about its axis in a suitable furnace, the weights at the end of each specimen rod produce the bending force that causes gradual deformation, measured as the angle of bending from the initial vertical position.

The centrifugal method has been used extensively to obtain diagrams of strength as related to composition, in which high-temperature strength is plotted completely across a binary diagram. There is now special interest in corresponding diagrams for ternary and more complex systems, including data on the variation with testing temperature of the composition of maximum strength. It is believed that the method can also be used to carry out a program of extremely long-time tests, possibly longer than the 100,000-hr. tests done in the United States. Studies would be made of the variations with time of testing of the structure and hardness of alloys. Curves of strength

*"A High-Temperature Centrifuge for Creep, Rupture, and Bend Tests", by I. I. Kornilov, *Journal of Metals*, March 1958, p. 187.



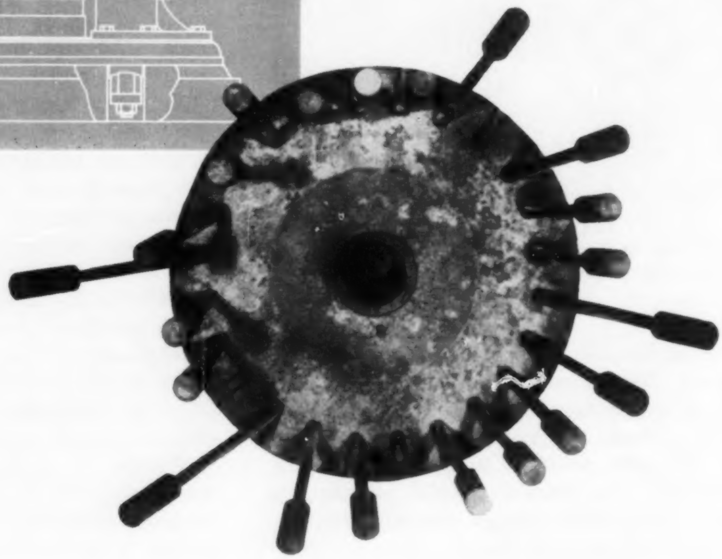


Fig. 2 – End View of Specimen Assembly in Kornilov's Centrifugal Testing Machine at the Conclusion of a Test. Inset shows details of the test equipment. Tests for small amounts of deformation, corresponding to creep conditions, as well as tests of long-time rupture strength can be carried out

as a function of composition would also be determined for various times of testing.

Laboratory of Mechanical Properties of Alloys

This laboratory, under the leadership of Prof. I. A. Oding, is working on a variety of problems, but the largest amount of space is taken up by testing equipment of various kinds, mostly of conventional design. There are large banks of machines for testing in rupture, creep, relaxation, and endurance. The general problem of fatigue failure is of great interest and is being studied mostly at room temperature although some testing is done up to 900° C. (1650° F.). A large-scale testing program on fatigue of railroad rails is also underway.

Relaxation is also extensively studied using Oding's "ring method", in which an almost complete ring is wedged open to produce the initial stress in the test section of the ring. At the Baikov Institute advantage has been taken of the speed and convenience of the ring method to choose alloys for bolts to operate at high temperatures.

Various aspects of creep and creep-rupture have been of continuing interest in this laboratory. For example, the effect of the surface layer was studied during rupture testing at 450° C. (840° F.) of low-carbon steel specimens 0.15 to 2.0 mm. (0.006 to 0.08 in.) in diameter. It was found that both the time to rupture and the amount of deformation at rupture for a given stress decreased appreciably for diameters less than 1.0 mm. (0.040 in.). Therefore, it was concluded that microspecimens cannot be employed to obtain creep and rupture data applicable to machine parts of normal size.

Statistical aspects of rupture-test data have been studied. For efficient achievement of reliability in a rupture curve, it is recommended that about 15 specimens be tested. These can either be distributed over the whole stress interval or used as groups of three at each of five stress levels.

Creep of special alloys has been investigated to determine the relative importance of deformation at grain boundaries and within the body of grains. Microscopic evidence of grain-boundary deformation was found in recrystallization, polygonization, and disappearance of twins in steels subjected to creep conditions. Evidence for deformation within the grains was obtained indirectly from measurements of microhardness and electrical conductivity. In specimens experiencing a decrease in creep rate, the average microhardness decreased, reflecting the decrease in density of dislocations. Conversely, conditions of increasing creep rate produced an increase in microhardness.

Measurements of electrical conductivity gave a similar agreement with theory. When the creep rate decreased, indicating a decrease in dislocation density, the conductivity increased. Later in the same test an increase in creep rate was accompanied by a decrease in conductivity. Therefore, it was concluded that deformation in creep occurs because of changes both within the grains and at the grain boundaries.

Professor Oding's laboratory has shown continuing interest in extending creep and rupture testing to unusual conditions of stress and temperature. Experiments have been made on varying the temperature during a test at constant stress, and on varying the stress in a constant-temperature test. Recently, the effect of complex stresses on creep of thin-walled tubes of 18-8 stainless steel at 600° C. (1110° F.) was studied. It was found that creep under ratios of shear stress to tensile stress from infinity to zero could be described adequately by the usual Hencky theory, although an exponential relation between creep rate and stress gave somewhat better agreement.

It is indicative of the reluctance of Soviet metallurgists to accept the dislocation theory that as late as 1958 Oding and Geminov published a general treatment of the theory advocating its use in the area of plastic deformation. Actually, Oding's group has been actively applying dislocation theory for several years, and this area is currently of major interest.

Oding has published a general analysis of creep phenomena based on the assumption that the rate of creep is proportional to the number of dislocations in position to move.* Also, Oding and Lepin† used an equation derived from dislocation theory to correlate the deformation characteristics obtained in relaxation tests and in creep tests. In this way it is shown that ordinary creep data can be used to predict relaxation strength or deformation under complex stresses. Experimental work in this area is being continued.

Several other aspects of dislocation theory are of current interest in Oding's group. Thermomechanical working of metals (the production of substructures) is being investigated as a means of increasing rupture strength or creep strength. Commercial high-temperature alloys are deformed at the test temperature – up to 400° C. (750° F.) – and then are tested for possible improvement in high-temperature strength. So far no general relations have been observed in the test results.

Work on metal whiskers is in the initial stages. This includes the growing of whiskers, testing their properties (including impact strength), and studying structural features such as orientation and crystal perfection.

Laboratory of Plastic Deformation of Metals

This laboratory is under the direction of I. M. Pavlov, who is well known for his books on rolling of metals. Research is broadly concerned with plastic deformation on a wide variety of projects. For example, investigations of conventional metalworking are carried out on commercial forging and pressing equipment, and there are extensively instrumented rolling mills for research in this area. A variety of equipment is available for testing the effect of deformation on experimental alloys. Impact testing, as an example, can be done at high temperatures in tension, or a curve of force of deformation versus time of impact can be obtained oscillographically, using a special tester fitted with a piezo-electrical crystal.

This laboratory is devoting considerable attention to a topic of great interest for high-temperature alloys – plastic deformation of brittle materials. Pavlov believes that whether or not deformation improves the high-temperature strength of a given alloy, it may be useful as a forming process or as a means for giving the ductility at room temperature required for fabrication operations.

*"Structural Theory of Creep of Metals", by I. A. Oding, contribution to the volume "Contemporary Problems of Metallurgy", Akademiya Nauk SSSR, Moscow, 1958, p. 564.

†"Determination of Characteristics of Deformation According to Creep Curves and Relaxation of Stress", by I. A. Oding and G. F. Lepin. *Metallovedenie i Obrabotka Metallov*, No. 4, 1959, p. 2.

Plastic Deformation of Brittle Alloys

The condition of stress during deformation of a specimen is of major importance. Specifically, tensile stresses, concentration of stresses, and nonuniform deformation must be minimized. An important tool for this purpose is the modeling of a given deformation procedure, including photo-elastic analysis of the stresses. When a desirable procedure has been chosen, special laboratory equipment is used to effect deformation under favorable conditions. For example, in one device a cylindrical specimen is elongated stepwise by radial compression between shaped dies.

Another important requirement for successful deformation of brittle materials is that the rate of deformation be very slow. Although it is not difficult to design the mechanical action of suitable equipment, there is the more serious problem of maintaining the specimen at the high temperature needed for successful working. This problem has been solved by the use of electrical resistance heating and automatic control of temperature during the deformation process. The electrical equipment includes transformers that reduce 380 volts to about 10 volts and deliver 3000 to 15,000 amp. Almost all of the devices for high-temperature deformation are equipped for this type of heating. Research is now being done on a machine that achieves the condition of gradual deformation by the repetition of very small deformations; repetition of stressing can be performed as often as 2000 times per min. on the equipment presently being used.

Recent studies in Pavlov's group on the working of brittle materials include an application to titanium alloys. Among titanium alloys that may require the special working conditions discussed above are high-temperature types, those containing large amounts of alloying elements, or alloys that must be given cold deformation. In the case of titanium alloys, there is a double advantage in using triaxial compression for producing uniform deformation since the same mechanical device can also protect the alloy being worked from contact with harmful gases.

Other research is being done on the effect on structure and properties when the deformation process involves a reversal of a previously completed deformation. Although the metals studied are iron, copper, and aluminum, it was intended that the conditions should approximate those met in the hot working of high-temperature alloys. For specimens that were returned to their original shape in the course of a given deformation (corresponding to 70% extension, for example), the microstructure showed relatively little distortion but hardness and strength were comparable to those of specimens subjected to normal deformation.

Cooperation Between Research and Industry

A feature of Soviet research that has special importance for Pavlov's laboratory is the close cooperation maintained between research institutions and industrial plants. Cooperative programs are carried on by his laboratory with at least three different plants and this permits industrial scale testing of promising new ideas. Formal agreements specify that certain alloys are to be supplied by the mill, that required equipment is to be made available, and that the necessary tests are to be run. In return, staff members of the research institute spend about half of their time at a given plant, which may be more than 1000 miles away.

This cooperative arrangement is mutually advantageous. The research group benefits from the availability of additional, large-scale equipment and also from stimulating contact with current industrial problems. A chief advantage to the plants is the rapid application of scientific advances — an achievement that has impressed recent American observers.

Conclusions

Soviet work on high-temperature alloys can be evaluated in two ways: its present status and an estimate of its future potential. Judged on the basis of the research work reviewed here, the present status might be described as "adequate", but below the level of the best work in the United States.

There are several reasons for predicting that the Soviet position will improve rapidly. New research institutes, such as the Academy of Sciences in Siberia, are rapidly being built; the present Baikov Institute itself was not in existence a few years ago. Scientific personnel in large numbers and of good quality is being made available through a system of competitive selection for higher education. Perhaps most important is the fact that stimulation for research comes not only from the technical literature of the western countries but also from the native industry, which is large, rapidly growing, and often quite modern.

Improved Aluminum Alloys for Bright Anodizing

*By F. HOWITT and I. H. JENKS**

Aluminum of commercial purity with balanced magnesium and silicon additions, or alloys of the Al-Zn-Mg-Cu family, all produced under rigid control in mill and heat treating operations, give an excellent combination of low cost, good strength, and high reflectivity. (L19; Al-b)

THERE HAS BEEN a steady increase for some years in the use of aluminum alloys where brightness is a requirement. In Europe, automobile manufacturers have been using bright anodized aluminum trim for 10 to 15 years; the material most commonly used has been superpurity aluminum (99.99%), either as such or with additions of certain alloying elements chosen to increase the strength but not to reduce seriously the response to the bright anodizing processes – that is to say, brightening by chemical means followed immediately by sulphuric acid anodizing.

Recently, bright anodizing has been introduced in North America for finishing automotive trim and components and parts of household appliances. In some of these, stronger metal is required than superpurity aluminum, and since this commands a price extra, the need to keep costs down so as to compete with the traditional chromium plate makes it desirable to substitute commercial purity aluminum as the base metal if possible. Such a situation has warranted much research. This article will review the principles involved in securing good response in the process, discuss the evolution of alloys to date, and predict some additional promising developments.

The Chemical Brightening Process

The objective of the operation is to produce a surface by chemical reactions which will be as smooth and bright as possible and which will be maintained in this condition by immediate anodizing for maximum light reflectivity.

The surfaces of most aluminum products such as sheet and extrusions appear bright and uniform as they come from the mill. Actually, in comparison with most other metals, they reflect light to a relatively high degree. However, the as-fabricated surfaces are not smooth, but consist, rather, of numerous minute ridges or peaks in more or less random arrange-

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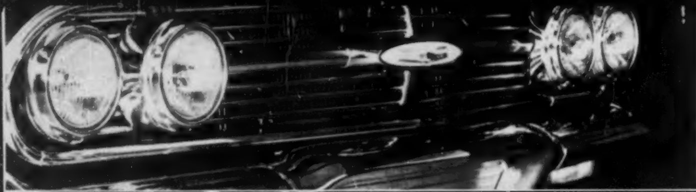
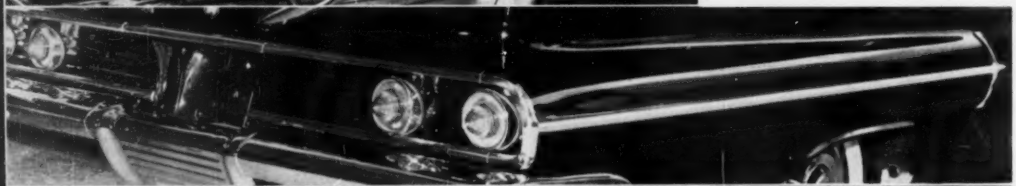
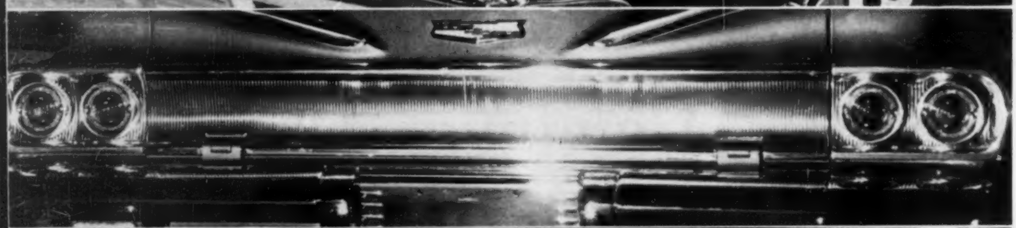


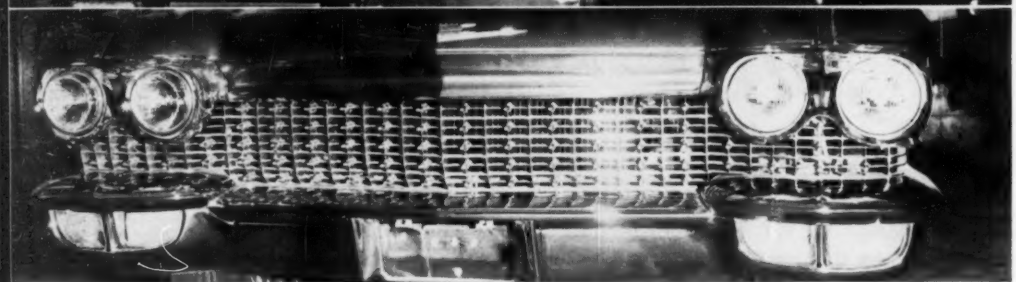
Chevrolet '60 front is almost all aluminum,



as is also the back and side trim of the Chevrolet.



The station wagon has even more aluminum trim,



and the Cadillac tops them all.

ment with troughs or valleys between or surrounding them. Incident light rays are therefore scattered and diffused with consequent loss, particularly of specular reflectivity (reflectance as by a mirror and distinct from diffuse reflectance). The first or chemical brightening step must reduce this irregularity and leave a smooth, uniform surface. Such a surface will have enhanced reflective properties which may be maintained by the second or anodizing step which produces an anodic protective layer sufficiently thin and transparent that no great loss of reflectivity occurs.

Sources of Irregularity of the Surface – Two types of irregularity will be found in aluminum products: (*a*) Mechanical roughness and (*b*) metallurgical irregularity.

Mechanical roughness arises from the manufacturing processes – for example, die markings on extrusions. While such irregularity can be smoothed by chemical brightening, reduction to tolerable proportions by careful control of the processing conditions is most desirable.

The most important contributing factor in metallurgical irregularity is the constitution of the metal or alloy. In common with all metals, aluminum (even of high purity, and aluminum alloys to a greater extent) is nonisotropic and slight differences in electrical potential exist from point to point which set up galvanic cells within the metal wherein one area becomes the anode and another the cathode. Such potential difference may exist between a grain boundary (where the boundary is the anode and is attacked) and the grain (which is the unaffected cathode). Some aluminum alloys contain intermediate constituents of different potential to the matrix; sometimes these may be a phase precipitated from solution during processing. In all of these situations, local galvanic cells of varying strength will exist at the surface. The current in these cells which governs the degree of attack will depend on the components of the cell (although other factors such as resistance and type of solution also play a part).

Surface contamination, or pickup from the manufacturing process, constitutes another source of irregularity. Most common are particles of iron and dirt picked up from the rolls during hot rolling. More serious still, slivers and fragmented aluminum oxide may make their appearance on the surface during hot rolling and are carried on through the cold rolling operation. These may be classed as

"contaminants" of the surface and they, too, will cause electrochemical differences.

It should also be appreciated that some of the manufacturing methods used in the modern mill may produce a nonuniform surface although some grades of metal are more susceptible to certain defects. For example, coarse grain tendency must be controlled during casting of superpurity aluminum. In metal of commercial purity, reticulation (a characteristic network of fine lines) may appear on rolled products after brightening and anodizing. Effects of an undesirable nature may appear in certain alloys, due to the orientation of the grains or of grain clusters. The influence of the type of deformation and the grain size of the metal on the response to bright anodizing has been investigated by French workers and will be briefly discussed later in this article.

It will be apparent that, in designing aluminum alloys for maximum response to chemical brightening, those systems should be chosen which will produce alloys of uniform chemical composition and which will not precipitate constituents of different potential from the matrix during any necessary heating or heat treatment. Furthermore, the alloys should be such that the deformation techniques will produce no detrimental effects.

Chemical Brightening – Optimum response to chemical brightening requires appropriate baths and techniques. The metal is attacked by suitable acid solutions; this attack by its very nature will dissolve different constituents at varying rates. In other words, "etching" will take place.

The composition of the bath may be varied to bring about more uniform etching. While baths of many compositions have been tried, the ones most commonly used in North America and the United Kingdom are based on phosphoric acid as the etching agent, and contain nitric acid as an essential oxidizing agent. In the United States and Canada, glacial acetic acid is generally added to give the best all-round characteristics.

The mechanism by which these solutions smooth and brighten the surface is very complex; the phenomena have been intensively studied and explanations have been advanced by several workers. It is generally agreed that the smoothing reactions are both chemical and electrochemical in nature. The simple chemical solution reactions require little comment, except to say that solution from projections occurs at a somewhat higher rate than from the intervening troughs. In the electrochemical reactions, the current in existing local cells is increased by the oxidizing agent, by the elevated bath temperatures, and sometimes by additions of certain heavy metals to the solution.

Metallurgical Factors Affecting Anodizing

Metallurgical factors play an important role in the second or anodizing step when the surface itself is converted to oxide. Unless this conversion is uniform in depth and constitution, reflectivity will be lost. Particles of different composition will react in different ways or at different rates to produce a nonuniform anodic film and roughen the interface between metal and oxide film. Such particles may consist of elements which, upon oxidation, produce crystal forms of different color and refractive index from the alumina film in which they are suspended. Sometimes the particles dissolve only partially, or not at all, and thus may be embedded in the film.

Considerable work has been done by various investigators to assess these effects – indeed, an adequate review of the existing literature would require a separate article. The consensus is that any precipitate or separate phase is undesirable, and the advantage of superpurity aluminum becomes evident. Similarly, if a multiphase structure can be homogenized by heat treatment, a uniform rate of oxidation and a correspondingly uniform oxide film may be expected. If it is necessary to use a heterogeneous alloy, the particle size and distribution are important. In general, particle size should be submicroscopic.

Materials for Bright Anodizing

On the basis of the principles and evidence discussed briefly above, the first choice of a material suitable for bright anodizing would be superpurity aluminum, in which the impurities are of a type and in such low amount that minimum interference is offered in both the brightening and anodizing steps. However, such metal has the disadvantages of low strength, susceptibility to grain growth during fabrication, and higher cost.

Some consideration has been given to aluminum of commercial purity (99.5 to 99.8% Al) for nonstressed applications such as household utensils and parts of appliances, but its handicaps are (*a*) deleterious effect of common impurities, particularly iron, in both the brighten-

ing and anodizing treatments and (b) that no appreciable increase in strength is provided.

Theory of Alloy Design – The fact that a bright, uniform surface can most readily be produced from an alloy of uniform composition suggests single-phase alloys with uniform solute distribution, free of inclusions.

In alloys strengthened by heat treatment, particular care will always be required to prevent precipitation of a phase of widely different electrochemical properties from the matrix. However, this does not rule out supersaturated alloys or those in which a precipitate may be taken back into solution. It does exclude any alloy systems where alloying elements may form phases which may precipitate during necessary thermal treatment and which cannot be redissolved. Manganese, iron, chromium and some other metals are eliminated as major components because their compounds are precipitated at the high temperatures required for homogenization and no subsequent treatment will redissolve them.

Such systems as Al-Mg, Al-Cu, Al-Zn and Al-Mg_2Si are promising because these alloying elements may be expected to produce the required hardening but will not bring about intolerable effects during bright anodizing. Also, these alloys are usually strengthened by rolling and extrusion and these manufacturing processes can be controlled to produce uniformity of structure or preserve homogeneity.

In commercial alloying practice, the binary systems are less frequently used than ternary systems. For example, in the aluminum-magnesium system silicon is usually added and the full mechanical properties are developed by heat treatments rather than by relying on strain hardening alone. Thus, certain phenomena associated with heat treatments must be considered in designing alloys for bright anodizing.

Precipitation hardening should not, as a rule, be a factor militating against satisfactory brightening and anodizing. For example, in the system Al-Mg-Si the magnesium silicide is scarcely distinct from the solid solution, and when precipitated as a separate phase it can be controlled to submicroscopic size and thoroughly dispersed. While overaging would produce particles of larger size, aging must be restricted not only to prevent growth of the particles but to retain the maximum mechanical properties.

The Al-Mg alloy system is the most promising. Two groups of this type are now in use in Europe and to a lesser extent in North America:

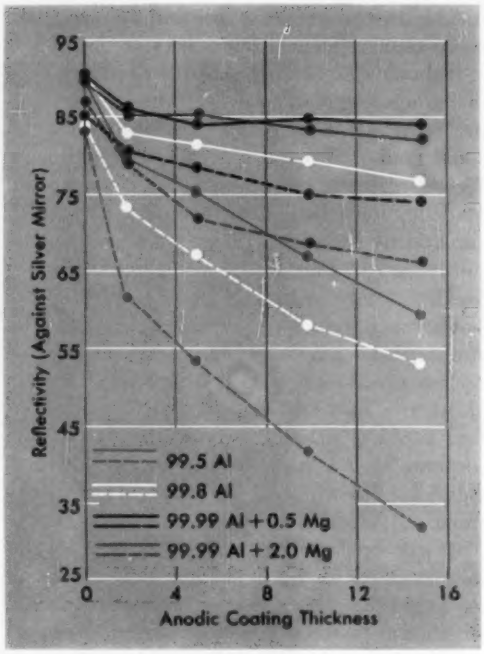


Fig. 1 – Effect of Metal Purity and Thickness of Anodic Film on Total Reflectivity (Full Lines) and on Specular Reflectivity (Dashed Lines) of Representative Types of Alloy. (Helling and Neunzig, Aluminium, *Vol. 9, 1952, p. 289)*

(a) Those based on superpurity aluminum (99.99%) and (b) those made from selected metal of commercial purity (99.8% Al). A representative group of commercially available alloys belonging to the first group, with typical compositions, is shown in Table I.

The strength of superpurity aluminum can be increased two to three times and still retain the ability to brighten and anodize with very little loss of reflectivity (see Fig. 1). The possible effects of natural impurities and of strengthening elements have been much discussed. Some recent research by W. E. Cooke and R. C. Spooner in Aluminium Laboratories in Kingston has studied the loss of specular reflectivity by incremental additions of copper, iron, magnesium, silicon, titanium, zinc, both individually and in certain combinations. The results have confirmed earlier work and the theories cited previously – namely (a) iron has the most deleterious effect on the bright anodized finish because of its low solubility in aluminum and (b) copper, magnesium, silicon, titanium and zinc, by virtue of their greater solubilities, have relatively little effect.

Table I – Commercially Available Bright Anodizing Alloys Based on Superpurity Aluminum

COUNTRY	DESIGNATION	COMPOSITION	
		MG	IMPURITIES
Germany	Al 99.99 R	—	Fe + Si + Cu + Zn + Ti: 0.01% max.
	Al R Mg 0.5	0.4-0.6%	Fe + Si + Cu + Zn + Ti: 0.02% max.
	Al R Mg 1	0.8-1.2	Fe + Si + Cu + Zn + Ti: 0.02% max.
	Al R Mg 2	1.5-2.5	Fe + Si + Cu + Zn + Ti: 0.02% max.
France	A 9	—	Fe + Si: 0.05% max.
	A 9 G 1	0.8-1.7	Fe + Si: 0.05% max.
	A 9 G 3	2.8-3.8	Fe + Si: 0.05% max.
Great Britain	S 1 (B. S. 1470)	—	Fe + Si + Cu: 0.01% max.
	SP 11	0.5 (nom.)	
	SP 12	1.0 (nom.)	
Italy and Switzerland	Reflectal	0.5-2.0	
North America	Lurium* D'Orium*	0.4-0.6	
		0.8-1.2	
		1.5-2.5	

*Trade names of alloys imported from Europe, usually regarded as equivalent to the corresponding German alloys.

The alloys of the second group have the advantage that they are based on the cheaper aluminum of commercial purity, have very satisfactory strength, and respond reasonably well to brightening and anodizing. Accordingly, several commercial alloys of this class have made their appearance recently. While these are not so brilliant as the superpurity alloys, the finish has been quite suitable for many applications. This favorable experience with aluminum of commercial purity plus 1% magnesium as sheet alloys with medium strength led to such alloys as AA 5357 and AA 5457*.

Messrs. Cooke and Spooner in our laboratory have recently studied the 1% magnesium alloy, based on superpurity and also on commercial purity metal, at varying levels of aluminum content (99.3, 99.5 and 99.8%). Addition of manganese in the range from trace to 0.3% increases tensile strength and affords some desirable control over grain size; to secure the optimum effect the manganese must remain in solid solution.

Al-Mg-Si Alloys – Very closely related to the Al-Mg alloys are the well-known medium-strength extrusion alloys of the quasi-binary Al-Mg_2Si system. Because Mg_2Si is highly soluble in aluminum and can be precipitated in submicroscopic particles, the Al-Mg-Si alloys with balanced magnesium-to-silicon ratio respond to brightening and anodizing in much the same way as the Al-Mg alloys. Even if the metal contains some slight excess of silicon, a clear anodic film may be expected.

A very logical bright anodizing possibility is the well-known commercial extrusion alloy Alcan 50 S (AA 6063) in which the magnesium and silicon are balanced and iron is at a nominal 0.25%. While this has good bright anodizing characteristics, a variation of the nominal composition, wherein iron and silicon have been decreased in varying amounts and 0.1% copper added, has proved interesting. I. Taylor of our laboratories found that if the silicon content of Alcan 50 S was dropped from the nominal 0.4% to 0.2%, the yield strength decreased but the specular reflectivity increased, and that fortunately artificial rather than natural aging restored the yield strength with no appreciable effect on reflectivity. Bright anodizing alloys of this type, known as Alcan C 50 S (AA 6463), are now available. Improved mechanical properties in both sheets and extruded products are in prospect, and the possibilities of securing additional strength by increasing the magnesium, silicon and copper while retaining satisfactory reflectivity are being investigated. The addition of other alloying elements is a very extensive area for research of which only a portion has been examined. *(Continued on p. 168)*

*Composition of AA 5357 is 0.12% Si, 0.17 Fe, 0.07 Cu, 0.15 to 0.45 Mn and 0.8 to 1.2 Mg. Composition of AA 5457 is 0.08% Si, 0.10 Fe, 0.05 to 0.20 Cu, 0.15 to 0.45 Mn and 0.8 to 1.2 Mg.

Staff Report

High-Temperature Research in Europe and Asia

One afternoon of a California symposium on high-temperature technology was devoted to talks by several conferees from overseas. They discussed some of the many and various research projects being carried on in England, France, Germany, Sweden, Norway and Japan. (A9, 2-62)

LAST OCTOBER, Stanford Research Institute sponsored an International Symposium on High-Temperature Metallurgy at Asilomar Conference Grounds located on the Monterey Peninsula in California. One afternoon of the conference was spent discussing progress in other countries. From England, France, Germany, the Scandinavian countries, and Japan came reports which were concerned with everything from solar furnaces to new theories for sintering reactions.

For example, a large amount of English research is on sintering and its effects, according to J. White of the University of Sheffield. One problem that occupies the attention of English metallurgists is, "What is needed for rapid sintering?" A number of workers, for instance, assume the presence of grain boundaries to be essential. They theorize that grain boundaries act as sinks at which vacancies are destroyed by the continuous removal of atom planes next to the boundaries.

New evidence for this hypothesis has been obtained from a study on the elimination of pores produced at the interface of copper sheets rolled together at 1470° F. On heating at 1875° F. in dry hydrogen, pores became spheroidized and their number decreased. Meanwhile, the average size of the remaining pores increased (showing that some diffusion of vacancies between pores was occurring) until the space between them was enough to permit grain growth across the interface. Very large grains were established. Thereafter, only small changes in pore size took place during heat treatment times which lasted up to 80 hr.

For comparison some sheet sections (in which pores had been spheroidized by short-time treatments at 1875° F.) were reduced to various degrees by cold rolling and then annealed for 10 min. at various temperatures. In these, pores were eliminated even as low as 750° F. whenever cold work was enough to cause recrystallization (with development of a large grain-boundary area) at the annealing temperature. At reductions which were insufficient to produce a large grain-boundary area, the pores were unchanged. Although cold work would raise the dislocation density, no continuous variation of the rate of pore removal with degree of cold work was observed. From this, the authors conclude that grain boundaries are the principal sinks for vacancies generated around pores, and that neither twin boundaries nor dislocations are strong vacancy sinks.

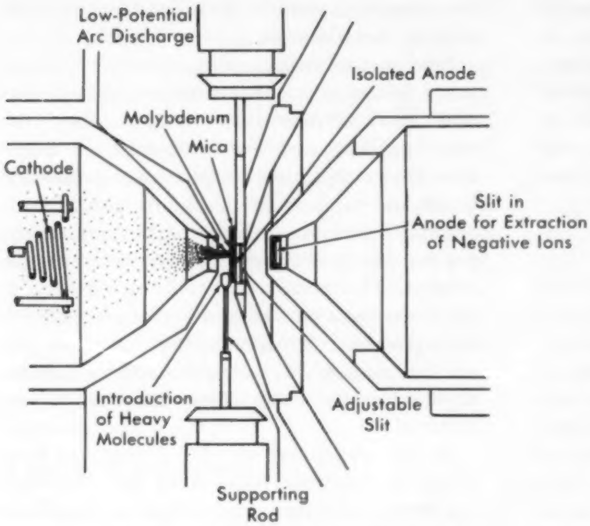


Fig. 1 — Experimental Device to Obtain Negative Ions of Heavy Molecules. Much research on free radicals is being done in Germany

Much other work in sintering is also going on. For example, an interesting practical adaptation of the zone melting technique is being used to sinter long rods and tubes of metals or ceramics. It involves passing a resistance furnace along the part formed from the unfired material. With a suitable temperature and speed of traverse of the hot zone, impermeable ware with high density can be produced to close tolerances without cracking.

Ways to form articles from powders are receiving the attention of several workers in the high-temperature field. Listed as examples by Mr. White are two methods for making graphite parts. In one the graphite is impregnated with furfuryl alcohol containing a suitable catalyst to promote polymerization. Then it is heated to 1850° F. to carbonize the alcohol. In the other, carbon is deposited in the pores of the graphite by pyrolysis of benzene vapor in nitrogen at 1400° F.

Work on the graphitic form of boron nitride was also discussed. First B_2O_3 was reduced with NH_3 at 1650° F., $Ca_3(PO_4)_2$ being used as a filler to prevent complete fusion of the mass. After reaction, the filler was leached with HCl to give a product containing 80 to 90% BN. This could be further purified by re-nitriding at 2200° F. with NH_3 or by heating to 3270° F. The latter method gave practically pure nitride.

Two methods were adopted for fabrication. In one, the 1650° F. product was hot pressed with Al and AlN to reduce the B_2O_3, or with CaO and Al_2O_3 to form a "glass". In the other, the pure material was hot pressed with BPO_4 or "glass" as a flux. The product obtained was chemically inert and was not wetted by soda glass. It had high electrical resistance when freed from moisture, and was considered promising as a crucible material and as a high-temperature insulator. Chief limitation was its low oxidation temperature, 1400° F.

There is still interest in cermets despite their lack of resistance to thermal and mechanical shock. For instance, there is much work on metal-ceramic mixtures as fuel elements in nuclear reactors. In these, the fissile material, which may be the oxide or the carbide of the fissionable element, is dispersed as small particles in a metallic matrix. Advantages claimed are high thermal conductivity and thermal shock resistance, and localization of fission product damage. Fuel elements of iron containing up to 50% of UO_2 have been extruded in steel sheaths.

The fabrication of Al-UO_2 dispersions (in plates) and of PuO_2-Th dispersions (by cold compacting and sintering) has also been described.

In the refractory field, a major development has been the discovery that the nature of the bond in chrome-magnesite refractories can be modified by the firing treatment. Normally, refractories of this type are manufactured from a mixture of crushed, graded chrome ore and finely ground magnesia. During firing, the latter combines with the low-melting magnesium silicates of the chrome ore to form the refractory compound forsterite (Mg_2SiO_4), while any lime present reacts to form the fusible silicate monticillite ($CaMgSiO_4$). Since excess magnesia is normally added, the fired brick consists of grains of highly refractory chrome spinel and periclase bonded together by these silicates. Failure of the material under load at high temperatures is determined primarily by the softening point of the latter.

Recently, it has been shown that when chrome-magnesite bricks are fired to 3100 to 3270° F., the silicate bond coalesces to form

discrete "islands" of silicate and is replaced by a magnesia-magnesioferrite bond of higher refractoriness. The change is accompanied by a marked improvement in the tensile strength at high temperatures. The most probable explanation is that the change represents a change of the system toward minimum interfacial energy between the phases.

Work in France

According to F. Trombe and M. Foex (Solar Energy Laboratory, Mont Louis, France), a lot of high-temperature research is also being done by Frenchmen. Solar furnaces take up much time and effort. Small (2 kw.) and medium (75 kw.) furnaces with automatic controls are now functioning, while larger furnaces are being built. One such furnace, which has a parabolic mirror (composed of 6000 small mirrors) about 180 ft. in diameter, is expected to produce 1000 kw. Its efficiency should be much greater than the smaller furnaces now in operation, according to Mr. Trombe.

Another interesting furnace for high-temperature work does not use refractories. Metal radiation shields (of molybdenum or electrolytic iron) replace them; such shields have a low thermal inertia and can be rapidly degassed under vacuum. With tungsten for the resistance elements, 4200° F. has been reached in high vacuum.

The French are also devoting some of their time to producing metals and alloys by electrolyzing molten salts. For instance, 99% zirconium has been made by electrolyzing a bath containing $ZrCl_4$, $CaCl_2$ and an alkaline chloride KCl or NaCl. Different alloys of zirconium with beryllium, aluminum, uranium, titanium and manganese have also been obtained from mixtures of $ZrCl_4$ or of K_2ZrF_6 with certain halogen compounds (of the previous metals, of course) in the presence of an alkaline chloride at 1560° F. Others have prepared tungsten by electrolyzing its minerals in a melt. Alloys of germanium-silicon have been produced from melts of silicate into which slight quantities of germanium oxides were added.

Other French workers have prepared silicon steels by electrolysis of silicates with a molten iron cathode. An arc melts the material, and electrolysis is then accomplished by direct current. Aluminum-calcium alloys have been prepared by direct electrolysis of calcium aluminate. These experiments were conducted in an economic study of the feasibility of using inexpensive materials such as blast furnace slags or metallic ores.

Among the many other research projects listed in this article, there are two which may offer ideas to American workers. They concern beryllium and aluminum nitride. Beryllium, for example, has useful nuclear properties, but its use has been limited by its lack of workability. However, ductility can be increased by purification, particularly with respect to oxygen content. Parts cast of beryllium are not as ductile as parts pressed and sintered from beryllium powder. Apparently, the thin oxide film on the surface of sintered particles inhibits crystal growth which seems to occur in cast material.

As for aluminum nitride, a way has been found to fabricate parts from this extremely refractory substance. A mixture of aluminum and aluminum nitride is exposed to nitrogen at high temperatures. The resulting material is reported to be homogeneous, compact, and highly resistant chemically. It is hoped that this material can be used for melting glass or aluminum in an oxidizing atmosphere.

Germany Makes Contributions

Research activity carried out by Germans was the topic of a report by Walter Lochte-Holtgreven of the Institute for Experimental Physics at Kiel, Germany. Judging from his talk, there is little occurring in German high-temperature research that would interest metallurgists. Most of the work is concerned with the electric arc, shock tube research, and various types of electric discharges. Electric arcs are used to produce chemical reactions (for organic analysis, as an example), or to separate elements or even isotopes of the same element. Some research on free radicals is done with shock tubes. An extreme example of this was the production of "pure sunlight"! How is this possible? Well, the light emitted by the sun is due solely to attachment of electrons to neutral hydrogen atoms. Conditions for this are extremely favorable at the sun's surface where the hydrogen molecules are completely dissociated, and many electrons are set free from elements with low ionization energy. These conditions have been very well approached at Kiel, where true sunlight was produced in a hydrogen-filled shock tube. The light was 50 times stronger than that from any other continuous radiation from the same source.

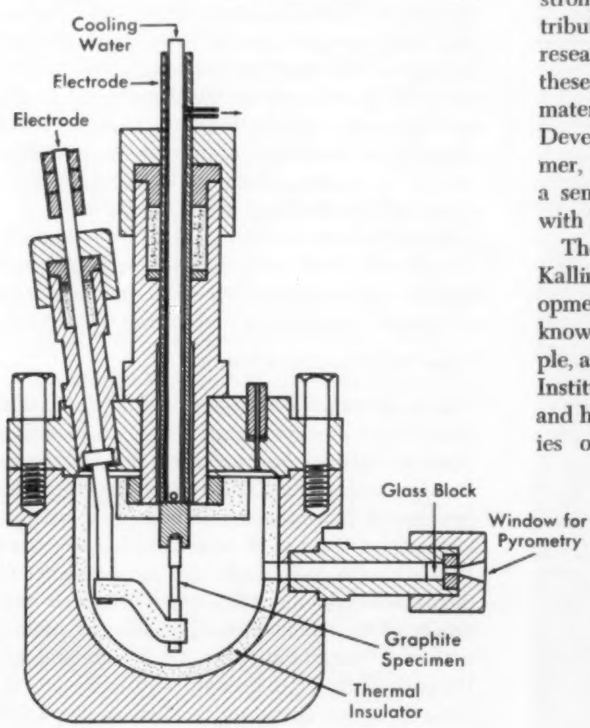
Negative ions of large molecules are being

investigated. Because these molecules are rather sensitive to impact, electrons must be added as gently as possible. This can be done in a highly condensed plasma obtained from a low potential arc, into which the large molecules are introduced slowly. The condensed plasma is obtained by magnetic compression inside a diaphragm. The negative ions are drawn out of the plasma by electric fields, and immediately investigated by mass analysis. Figure 1 illustrates the process. This method of mass analysis of negative ions may become of the greatest importance to the chemical analyst because individual masses can be analyzed from molecules which cannot be separated by chemical methods.

Progress in Scandinavia

The report by H. Flood (Institute of Silicate Science, Norwegian Institute of Technology, Trondheim, Norway) indicated that research corresponded fairly well to the economic interests in the four Northern countries, Denmark,

Fig. 2 — Pressure Vessel for Melting Carbon. Small specimens of carbon can be melted by moderate voltages and amperages if the pressure is high enough. This work is performed in Japan



Sweden, Norway and Finland. Denmark, for instance, has an old porcelain industry of international repute. This is also true of Finland, though that country has metallurgical interests as well. Her copper ores are a good example. Sweden, of course, has had a strong metallurgical position for many years. Large reserves of rich iron ore helped to make her a leading producer of sponge iron, and she produces copper, gold and several other metals as well. Sweden is also known for her glass, porcelain, and earthenware. In Norway, most work has been planned to make use of the vast reserves of hydro-electric power. As a consequence, Norway has become a leading producer of aluminum and ferro-alloys.

Since research generally follows the industrial pattern of each country, each national technical school differs in the training it offers and the projects it conducts. Consider Denmark, for instance. Because her metallurgical resources are nil, her metallurgical research is the same. Virtually all work is devoted to ceramics. Finland is in much the same position, and little is being done there, metallurgically speaking. As a consequence, Mr. Flood's talk was concerned mainly with research in Sweden and Norway.

As mentioned before, Sweden has a very strong position in metallurgy. The many contributions which have been made by Swedish researchers reflect this position. Typical of these is "Super Kanthal", a heating element material which can be used up to 3000° F. Developed by the Kanthal works in Hallstahammer, Sweden, this alloy is reported to be quite a sensation in laboratories that are concerned with high-temperature work.

The work of such Swedish metallurgists as Kalling, Rennerfeld, and Wiberg in the development of sponge processes is internationally known. This work is still going on. For example, at the Kungliga Tekniska Högskolan (Royal Institute of Technology) in Stockholm, Wiberg and his fellow metallurgists continue their studies on sponge iron. Other current investigations taking place there include studies of the reduction of iron oxides. Workers have found that Fe_3O_4 (magnetite) is reduced more slowly than Fe_2O_3. Therefore, they feel that reduction velocity may be improved by a preliminary oxidation of the magnetite. The Swedes are also doing much high-temperature

(*Continued on page 174*)

Welding a Pressure Vessel for a Canadian Test Reactor

By A. M. BAIN,
A. H. CLARK
*and M. J. LAVIGNE**

Fabrication of a pressure tank from Type 347 stainless steel posed a serious welding problem because of the thick section required. Welding was done in such a way as to expose Type 347 stainless – either as a weld or backing bar – to the interior of the tank, where corrosion resistance is important, and backing this with Type 307 + 1% Mo which has better hot ductility. (K1, T26q; SS)

A SUCCESSFUL TECHNIQUE for welding heavy sections of Type 347 stainless steel has been developed by the Canadian Westinghouse Co. Ltd., Hamilton, Ont., and the Dominion Bridge Co. Ltd. of Montreal, Quebec. The technique was employed during fabrication of a test loop surge tank for the experimental NRU reactor at Chalk River, Ont. (see *Metal Progress,* January 1959, p. 90).

Tapped into the reactor pile, the test loop (Fig. 1) permits study of radiation effects on fuel elements, reactor construction materials, and fuel coolants under conditions of high neutron flux, temperature, and pressure.

This article discusses the problems encountered in designing and fabricating the surge tank of the test loop. Function of the tank, which is shown in Fig. 2, is to (*a*) pressurize the system at 2400 psi. to prevent boiling of the liquid within the loop at operating temperature (up to 630° F.), (*b*) permit thermal expansion and contraction of the loop coolant throughout the temperature range without the necessity of make-up or bleed systems, (*c*) absorb pressure surges that may occur during operation of the loop, and (*d*) provide a suitable method of boiling off and collecting gases produced within the loop during operations.

Requirements of the A.S.M.E. Unfired Pressure Vessel Code and the Ontario Boiler and Pressure Vessel Act governed design, selection of material, fabrication, and testing of the tank.

Type 347 Stainless Chosen

The corrosive conditions under which the vessel is to operate dictated the use of either stainless clad carbon steel or the 300 series stainless steel plate. Clad plate was ruled out because of the difficulty of making a satisfactory closing weld joint from outside the vessel. It would also have made the large number of nozzle attachments difficult to fabricate if continuity of the stainless steel surface in contact with the loop fluid were to be maintained. Because of its high strength and corrosion resistance under operating conditions, Type 347

*Mr. Bain is chief engineer, Platework Div., Dominion Bridge Co. Ltd., Montreal, Quebec. Mr. Clark was formerly design engineer, Atomic Energy Div., and Dr. Lavigne is manager, mechanical-metallurgical section, Research and Development Laboratories, Canadian Westinghouse Co. Ltd., Hamilton, Ont.

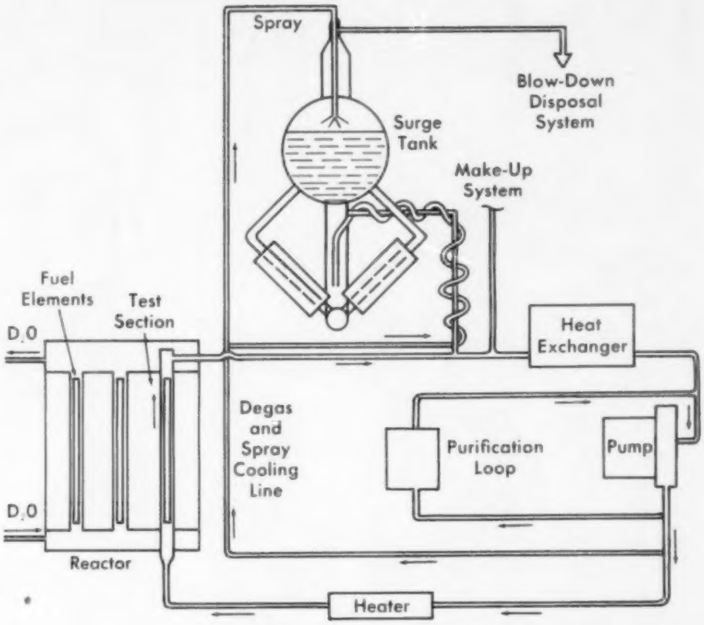


Fig. 1 – Schematic Diagram of the Loop of the Nuclear Reactor at Chalk River, Ont. The system, used in the study of radiation effects on fuel elements and reactor materials, is designed for operation up to 630° F. at 2400 psi.

stainless steel* stabilized with columbium but with a limitation on tantalum content was chosen. The vessel was fabricated from 3-in. thick plate formed into a shell (26 in. I.D.) with a single longitudinal welded joint. Each end was closed with a dished head welded into place. Although welding may alter the corrosion resistance of Type 347, it was believed that this problem would be easier to overcome than that of heat treating an unstabilized grade of stainless steel after fabrication.

So that a welding technique could be specified with confidence, we initiated a program to determine the welding characteristics of thick plates of Type 347 stainless.

Two Electrode Compositions Used

The choice of welding electrodes was governed by two considerations other than mechanical properties. First, corrosion resistance of the weld metal in contact with the vessel's

*Composition: 18.52% Cr, 11.56 Ni, 0.062 C, 1.54 Mn, 0.024 P, 0.018 S, 0.55 Si, 0.71 Cb, 0.06 Ta.

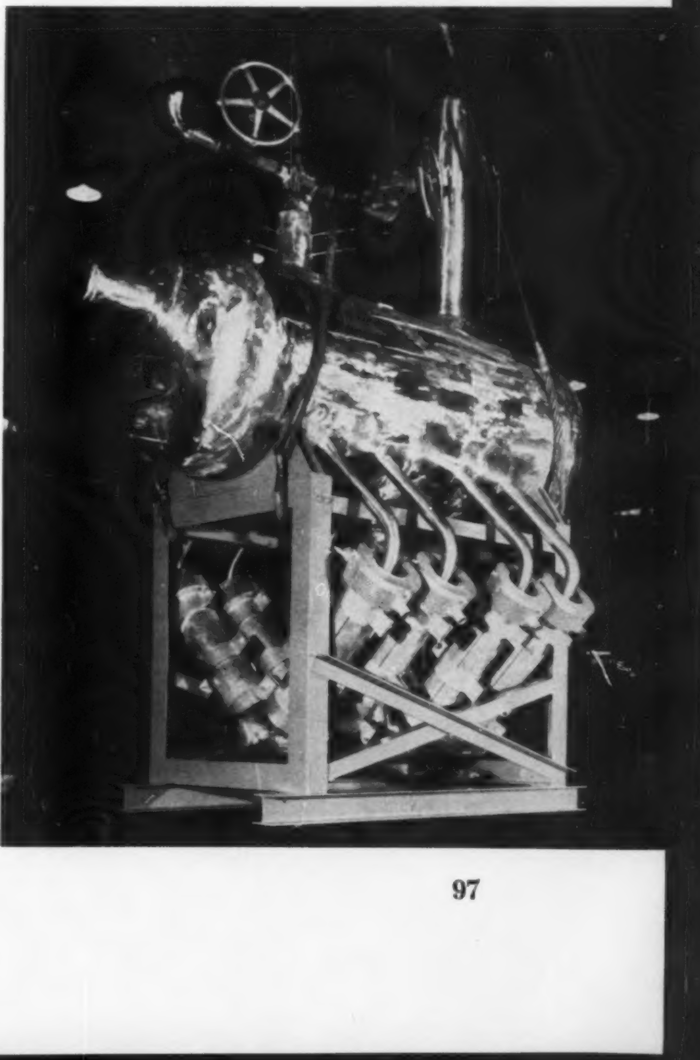


Fig. 2 – Surge Tank After Fabrication. Made from Type 347 stainless steel, 3 in. thick, the tank contains three welded joints – a longitudinal seam running the length of the cylinder part of the tank, and two circumferential welds joining the heads to the ends of the shell

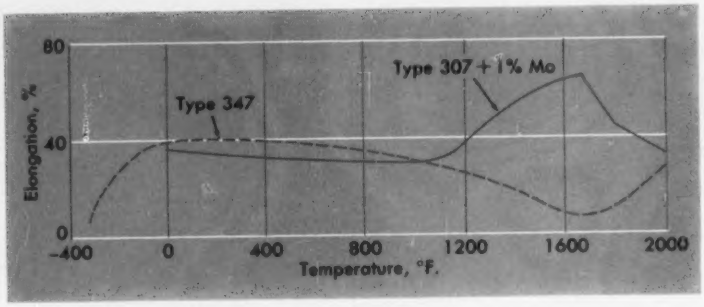


Fig. 3 – Effect of Temperature on Ductility of Type 347 and 307 + 1% Mo Stainless Steels. Although more corrosion resistant than 307 + 1% Mo, Type 347 is susceptible to hot cracking

contents must approximate that of the plate material. Second, brittleness of the weld metal at high temperatures should be minimized to reduce the risk of hot cracking. We planned to meet these needs by using the corrosion resistant Type 347 rod only for the inner ¼ in. of deposited metal where the restraint against shrinkage is less than that of subsequent layers and where corrosion resistance equal to that of the parent metal is required. The remainder of the groove not exposed to the contents of the tank would be filled with Type 307 + 1% Mo rod. According to Heuschkel (*Welding Journal*, December 1956), this weld metal has better ductility (and less corrosion resistance) than Type 347 at elevated temperatures. The striking difference in the hot shortness of the two alloys is shown in Fig. 3.

Weld Groove Design

Preliminary tests indicated that the double-V groove, with its smaller component on the inside of the vessel, would make the best weld for the shell's longitudinal joint. The joint form (Fig. 4) permits the use of different types of weld filler metal – E-347 at the inside surface of the tank, backed up with E-307 + 1% Mo.

Design of the circumferential joints between each dished head and the shell was governed by the fact that once the second head was attached there would be no access to the inside of the vessel for welding. At least one of these joints must have all the welding done from the outside. Thus, an internal backing bar which would insure complete fusion and a relatively smooth inner surface to prevent adherence to radioactive particles during service would be required.

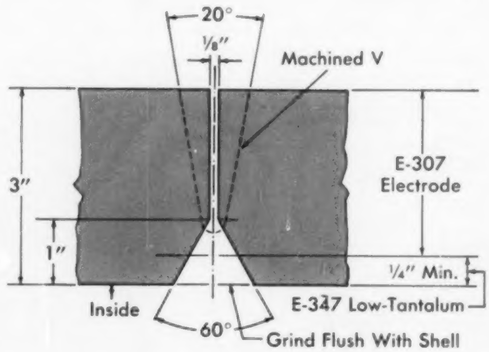
The backing strip form adopted for both circumferential joints (Fig. 5), known as E.B. backing, was developed by Electric Boat Co.

It was thought advisable to determine the quality of the weld produced by the proposed technique. The scope of the investigation covered ultrasonic and radiographic tests of welded samples, macro and micro-examination of the same samples under various metallurgical conditions, a short study of the alpha-to-sigma phase transformation in the Type 307 + 1% Mo weld metal, and the effects of combined temperature and stress cycling of the Type 307 + 1% Mo weld metal.

For this purpose two strips 24 × 3 × 3 in. of the Type 347 stainless steel plate to be used in the fabrication of the vessel were welded together by the fabricator, Dominion Bridge Co. Ltd. The procedure proposed for welding the heads to the shell, described in Table I, was used. The steel plates were supplied to the fabricator in the annealed and pickled condition. Table II shows the chemical composition of the electrodes.

Ultrasonic, radiographic and macrographic examinations indicated that the test welds con-

Fig. 4 – Cross Section of the Longitudinal Joint of the Surge Tank. E-347 low-tantalum electrodes were used on the inside surface of the tank where resistance to corrosion is important. Remainder of the joint was filled with Type 307 + 1% Mo because it has better hot ductility



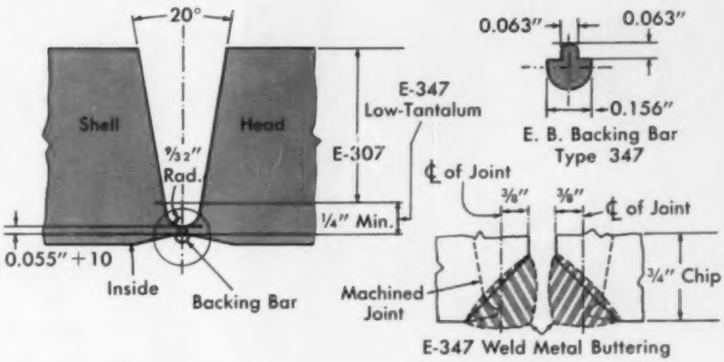


Fig. 5 – Circumferential Joint Between Each Head and the Shell. Backing bar exposes a relatively smooth surface on the side of the tank thus avoiding pickup of radioactive particles. "Buttering" with E-347 electrodes before machining the backing bar joint provides metal containing about 5% ferrite which minimizes the chance of crack formation at the joint during welding

tained only a few small slag inclusions of minor importance, but no cracks. Microstructures of the weld metals showed no sigma phase, but the study of ferrite decomposition in Type 307 + 1% Mo revealed that sigma formed in a few minutes at 1400 and 1500° F. For this reason – and to avoid cracking the Type 347 steel, which is sometimes brittle when heated to 2450° F. and cooled through both 2450 and 1800° F. –it appeared advisable to cool each bead rapidly during welding by maintaining an interpass temperature of less than 100° F. Cycling tests made on the stress-relieved sample by heating it between 200 and 700° F., while simultaneously applying stress between 0 and 14,800 psi., didn't change the microstructure or produce cracks in the Type 307 + 1% Mo weld metal.

The dished heads were hot formed from 42-in. diameter blanks. These were heated to 2100° F. and partially formed at a temperature in excess of 1800°F. This temperature limitation is required because of the hot shortness of Type 347 stainless. Final shaping of the partially formed head, reheated to 2100° F., was completed in the same die, again above 1800° F. The head was then immediately returned to the furnace – now at 1950° F. – and held for 3 hr. Finally it was put back into the cold die and held there until black to simulate a quench.

The shell was cold formed in the 2500-ton press. Forming was done in nine steps with five intermediate heat treatments to eliminate cold working effects of the forming process. Since there was only one longitudinal seam, the later stages of the forming were done by applying the load from the press to the die through a special blade, thus permitting the shell to be formed to an almost complete circle. The open edges were then squeezed to within 1/8 in. of each other. Intermediate heat treatments consisted of heating to 1000 to 1150° F., holding

Table I – Welding Procedure for Circumferential Joints*

Bead No.	Electrode†	Current	Voltage
1 (backing-bar fusion weld)	3/32 in. thoriated tungsten	90 to 110 amp.	14 to 18
2 + 3	1/8 in. Type 347	90 to 110	26
4 + 5	5/32 in. Type 347	125 to 145	26
6, 7 + 8	3/16 in. Type 347	150 to 170	26
9 to 80 incl.	3/16 in. Type 307 + 1% Mo	150 to 170	26

*Base metal: Type 347 stainless steel, 3 in. thick.

†Shielded with argon (15 cu.ft. per hr.) during welding. In addition, the backing bar was protected during fusion and the next two passes by argon on the inside surface of the tank.

Table II – Chemical Composition of Electrodes

Electrode	C	Mn	P	S	Si	Cr	Ni	Cb	Mo
Type 347 (1/8 in. diameter)	0.071	2.26	0.03	—	0.68	20.25	9.52	0.65	—
Type 347 (5/32 in.)	0.075	1.9	0.021	0.015	0.34	20.35	9.73	0.87	—
Type 347 (3/16 in.)	0.071	1.72	0.030	0.022	0.48	20.63	10.01	0.84	—
Type 307 + 1% Mo (3/16 in.)	0.101	4.28	0.027	—	0.34	19.75	9.53	—	1.04

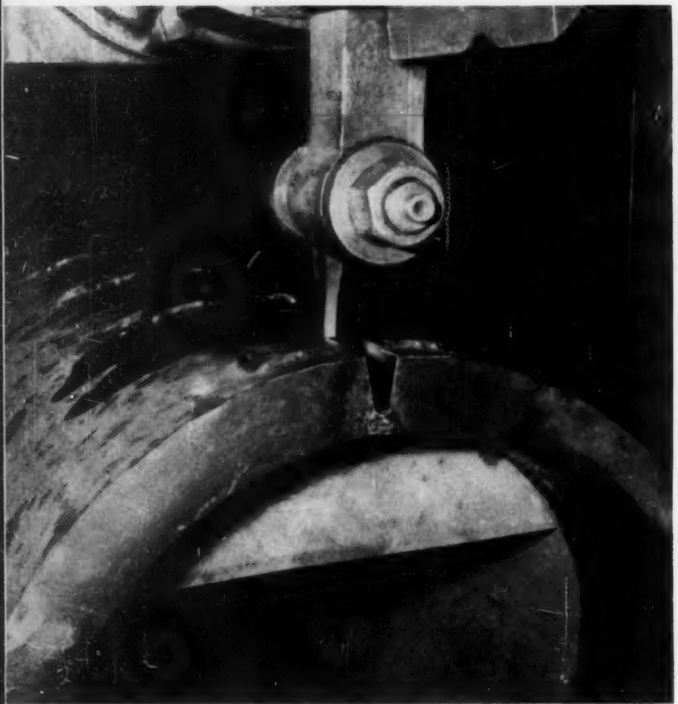


Fig. 6 – Machining the Outer 20° V Groove of the Longitudinal Seam of the Shell. Inner V has been filled with Type 347 and 307 + 1% Mo weld layers

for 3 hr. as a thermal stress-relief, then heating to 1700 to 1750° F., holding for 3 hr. and then water quenching.

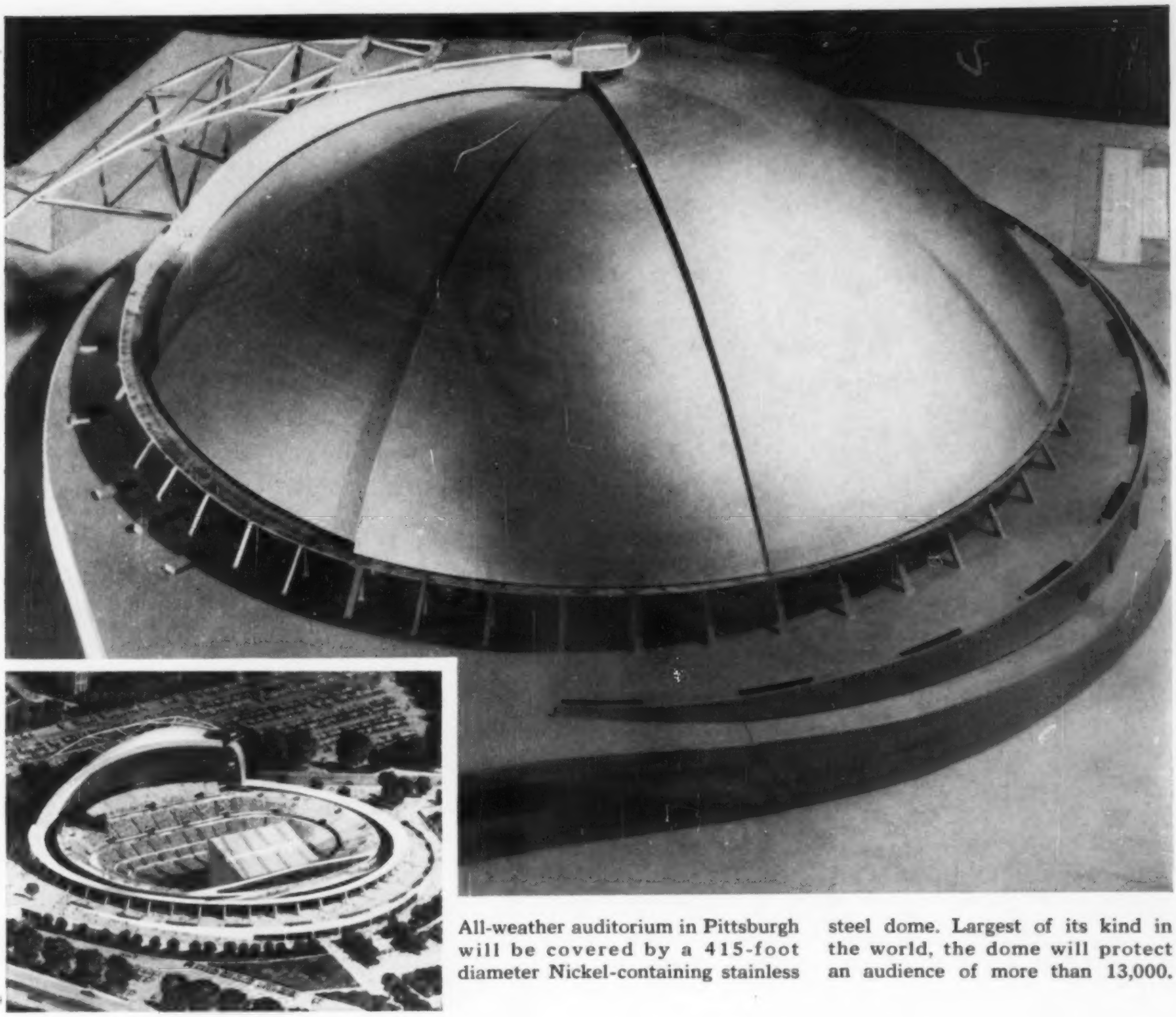
The metallic arc welding sequences for the longitudinal joint were performed manually and consisted of filling the 60° V on the inside of the joint to within ¼ in. of the inside surface using Type 307 + 1% Mo electrodes. Dye penetrant checks were made after the first root pass and at weld depths of ⅜ and ¾ in. The inside groove was then completed using Type 347 rod. At this stage, the 20° outside groove was machined to sound metal (Fig. 6), checked radiographically, and welded up with the Type 307 + 1% Mo electrode. This weld was checked with a dye penetrant at ½-in. intervals and radiographed again when the groove was half filled and at full depth. Any detectable discontinuities were repaired and re-examined after each successive examination. When completed, the cylinder was again heat treated by bringing it to 1000 to 1150° F., holding for 3 hr., then heating to 1950 to 2050° F. and holding for 3 hr., followed by a water quench. It was then descaled and rounded up in the 2500-ton press.

Prior to machining the grooves for the circumferential joints, ¾-in. bevels at 45° were chipped at the inside corners of both heads and shell. Corners were then rebuilt (buttered) with Type 347 weld layers. This provided metal with about 5% ferrite to insure that no cracking would occur in the heat-affected zone of the base metal during welding of the E.B. backing bar in the groove. Weld metal containing ferrite is less subject to hot cracking than the truly austenitic plate. Head flanges and their corresponding shell ends were then machined so that the E.B. backing bar would fit perfectly. Details of the buttered edges, the E.B. backing, and the machined grooves are shown in Fig. 5.

The first head was assembled to the shell with its backing bar as though there were no means of access to the inside of the vessel to make sure that the procedure and fit-up would be satisfactory for the second head. A sharp pointed 2% thoriated tungsten electrode, 1/16 in. in diameter, was used to fuse the backing bar in place. Argon, introduced through a perforated diaphragm installed within the vessel just to the shell side of the joint, protected the root face of the backing ring during fusion. This arrangement served to retain the gas at the first head joint without a disruptive positive flow. The root passes were checked with a dye penetrant, and radiographed and repaired where necessary. Next step in joining the head to the shell consisted of filling the first ¼ in. of groove depth by metallic arc welding, using Type 347 coated electrodes. The remainder of the groove was filled with Type 307 + 1% Mo. Frequent dye penetrant and radiographic checks between weld passes permitted close quality control.

Before attaching the second head, fitting and opening reinforcements in the shell were welded in place. The shell was braced to prevent distortion of its open end. Welding the second head to the shell was accomplished in the same manner as the first except that the entire vessel was filled with argon to protect the root of the backing ring.

The entire vessel with all pipe connections was stress-relieved at 900 to 950° F. for 26 hr. followed by air cooling. Extensive checking by dye penetrants, ultrasonics, radiography, hydrostatic pressure (4800 psi.) and helium gas (10 psi.) revealed no defects.



All-weather auditorium in Pittsburgh will be covered by a 415-foot diameter Nickel-containing stainless steel dome. Largest of its kind in the world, the dome will protect an audience of more than 13,000.

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Suggest something to you? Can stainless help you solve a problem involving corrosion, stress, appearance, temperature extremes? The way to find out is to write us. We'll see if Nickel-containing stainless steel – or some other nickel alloy – may be just what you're looking for.

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NICKEL MAKES ALLOYS PERFORM BETTER LONGER

Machining Ultra-High-Strength Alloys

Source: Metcut Research Associates, Inc. **Sheet II of Two**

Alloy and Hardness (*a*)	Tool (*b*)	Tool Geometry (*c*)	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-Land (*d*)	Cutting Fluid
		Slotting – Carbide Tools. Cutter: 6-In. Diam., 6-Tooth Brazed-Tooth Slotting Cutter							
A.I.S.I. 4340; C-52	C-2	AR: 5°; ECEA: 1°; RR: −10°; Cl: 8°; CA: 45° × 0.030 in.	0.250	1 in.	0.005 in./tooth	190 ft./min. 275	225 in. 150	0.016 in.	None
VascoJet 1000; C-52	C-2	AR: 5°; ECEA: 1°; RR 10°; Cl: 8°; CA: 45° × 0.030 in.	0.250	1	0.005	190 350	300 180	0.012	None
		Drilling Through Holes – High Speed Steel Tools. Cutter: ¼-In. Diam. Stub Drill							
A.I.S.I. 4340; C-50	T-15	2-flute, 118° crankshaft point 7° clearance	0.500 in.	—	0.001 in./rev.	30 60	100 holes 20	0.016	(*f*) (*f*)
A.I.S.I. 4340; C-52	T-15	2-flute, 118° crankshaft point, 7° clearance	0.500	—	0.001	20 60	34 8	0.016	(*f*)
VascoJet 1000; C-52	T-15	2-flute, 118° crankshaft point, 7° clearance	0.500	—	0.0005	20 60	26 7	0.016	(*f*)
AM-350	T-15	2-flute, 118° crankshaft point, 7° clearance	0.500	—	0.200	20 60	107 28	0.016	(*f*)
A-286	T-15	2-flute, 118° crankshaft point, 7° clearance	0.500	—	0.500	20 60	51 17	0.016	(*f*)
		Tapping Through Holes – High Speed Steel Tools. Cutter: 5/16-In., 18 Threads/In. Taper Tap							
A.I.S.I. 4340; C-50	M-10	4-flute 60% thread	0.500	—	—	5 20	146 30	Tap breakage	Highly chlorinated oil
	M-10	4-flute 75% thread	0.500	—	—	5	13	Tap breakage	Highly chlorinated oil
A.I.S.I. 4340; C-52	M-10	4-flute 60% thread	0.500	—	—	5	75	Tap breakage	Inhibited trichloroethane
	M-10	4-flute, 60% thread	0.500	—	—	5	7	Tap breakage	(*g*)
	M-10	4-flute, 60% thread, 0.015 in. land	0.500	—	—	5	18	Tap breakage	(*g*)
AM-350	M-10	4-flute, 75% thread	0.500	—	—	5 9	200 25	Tap breakage	Highly chlorinated oil

(*a*) VascoJet 1000 and 4340 are quenched and tempered; A 286 and AM-350 are solution treated and aged.
(*b*) C-2, C-6, and C-8 are carbides; T-15 is a tungsten-base, high speed toolsteel, and M-10 is a molybdenum-base, high speed toolsteel.
(*c*) AR = axial rake; RR = radial rake; CA = corner angle; SR = side rake; BR = back rake; SCEA = side-cutting edge angle; ECEA = end-cutting edge angle; Cl = clearance.
(*d*) wear on the peripheral flank of the cutter.
(e) applied as spray mist through axis of cutter.
(*f*) highly sulphurized oil + light machine oil (1:1).
(*g*) chlorinated oil + inhibited trichloroethane (3:1).

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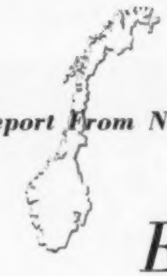


Report From Norway

Electropolishing of Columbium and Tantalum

*By O. J. KRUDTAA and K. STOKLAND**

Electropolishing in a solution containing hydrofluoric acid proves best for preparing columbium and tantalum specimens for microhardness measurements. (M20p; Cb, Ta)

IN DETERMINING MICROHARDNESS of polished specimens of columbium, the values obtained seemed to depend on the nature of the polishing process. Mechanical polishing, by using alumina or diamond paste in alcohol, for example, gives an undesirable work hardening effect. It was, therefore, found necessary to polish by an electrolytic method. Since columbium and tantalum show a similar chemical behavior, experiments were also performed on the latter.

A few investigations on electrolytic (anodic) polishing of columbium and tantalum are recorded in the literature. Cottin and Haissinsky† reported good results for columbium with an electrolyte containing hydrofluoric and nitric acids. An electrochemical process for polishing tantalum for commercial purposes has been patented by Gall and Miller (U.S. Patent No. 2,466,095) and by Jenny (U.S. Patent No. 2,742,-416). The latter technique employs an electrolyte containing a relatively small proportion of hydrofluoric acid together with a large amount of hydrochloric or sulphuric acid.

For our work, metal specimens were taken from pure columbium strip (99.97% Cb), 5 mm. thick, as received, and 0.1-mm. sheets, rolled from pure tantalum wire (99.9% Ta). After rolling, the tantalum specimens were heat treated in vacuum (0.0001 mm. of Hg) at 2100° F. for 1 hr. to recrystallize the grains. In the experiments the specimens were always the anode, the cathode being made of platinum.

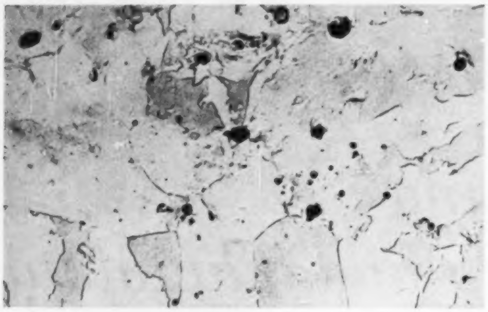
Most of the tests were carried out at three current densities, various voltages and with three rates of electrolyte circulation. The apparatus used was a DISA-Electropol, made by H. Struers Chemiske Laboratorium, Copenhagen (available in the United States at William J. Hacker & Co., Inc., P. O. Box 646, West Caldwell, N.J.).

Preliminary Tests

All the electrolytes which have been successfully used contain hydrofluoric acid. However, in some of our preliminary experiments, a number of other acids were tried. These were sulphuric, phosphoric, nitric, and citric acids in water or methanol, either alone or together. To some of the solutions small amounts of ammonium sulphate or an inhibitor (Dr. Vogel's

*Respectively, metallurgical engineer and head, Dept. of Inorganic Chemistry, Central Institute for Industrial Research, Blindern, Oslo, Norway. This work was sponsored in part by the Wright Air Development Center of the Air Research and Development Command, USAF, through its European Office under contract No. AF 61(052)-90: Oxidation of Niobium.

†See *Journal Chimie Physique*, Vol. 47, 1950, p. 731.

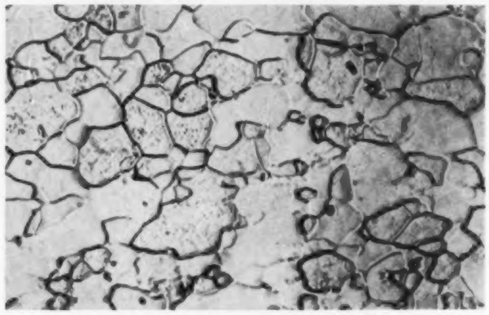


Electrolyte I – Columbium 150 ×

Composition:

Nitric acid (sp.gr. 1.4)	170 ml.
Hydrofluoric acid (sp.gr. 1.16)	50 ml.
Citric acid	5 g.
Methanol	510 ml.

Polishing time: 40 sec.
Current density: 5 amp. per sq.cm.
Velocity of electrolyte: 5 to 6* (that is, 16 to 18 cm. liquid column)
Etch in electrolyte at low circulation rate with no current for 2 to 3 min.



Electrolyte II – Tantalum 600 ×

Composition:

Nitric acid (sp.gr. 1.4)	170 ml.
Hydrofluoric acid (sp.gr. 1.16)	50 ml.
Ammonium fluoride	30 g.
Methanol	510 ml.

Polishing time: 40 sec. to 2 min.
Current density: 3.5 amp. per sq.cm.
Velocity of electrolyte: 6 to 7* (that is, 18 to 20 cm. liquid column)
Etch in electrolyte at low circulation rate with no current for 2 to 3 min.

Sparbeize) were added. Some experiments were also carried out with a sodium hydroxide solution as the electrolyte.

Electropolishing in solutions which contained no hydrofluoric acid proved unsuccessful. During electrolysis, a solid gray to black layer formed on the anode. It could not be removed at any current density within the range investigated (3 to 6 amp. per sq.cm.).

The high voltages needed (100 to 150 volts) to obtain the higher current densities indicated high electrical resistance in the layers formed on the anodes. Sparking also occurred and a white fume was evolved. The pronounced passivating effect ("valve effect") obtained on the columbium and tantalum anodes has also been reported by other investigators.

In view of the negative results, electrolytes based on hydrofluoric and nitric acids were tried. Some contained small amounts of ammonium fluoride or the above-mentioned inhibitor. As before, both water and methanol were used as solvents.

The polishing effect and quality obtained with these solutions were much better than with those tried at first, and the best of them gave entirely satisfactory results. Addition of ammonium fluoride proved beneficial in polishing tantalum, but had no effect on columbium. To obtain as satisfactory results as possible, a series of experiments was carried out in which electrolyte composition, current density and circulation rate were varied. The optimum electropolishing techniques given above were found to be most suitable.

Both metals can be etched by circulating the electrolyte for 2 to 3 min. at a reduced rate with the voltage shut off. This etching method gives a clean surface with sharp grain boundaries.

Pores Cause Uneven Surface

Mechanical and electrolytic polishing revealed pores on the polished surfaces of both metals, though more pronounced on the columbium than on the tantalum specimens. They

*Refers to the adjustment which controls the opening of the circulating pump outlet of the DISA-Electropol apparatus. Best polishing results were obtained with an aperture plate opening of 7 mm. diameter. Liquid column is height to which electrolyte rises in a glass tube placed vertically over the aperture plate opening.

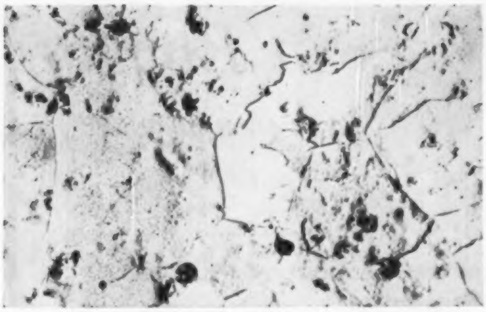


Fig. 1—Columbium Electropolished Under Conditions Given on Page 102. Uneven surface of porous compacted and sintered metal probably results from highly localized variations in current density as metal is removed and pores are opened up. 150 ×, oblique illumination

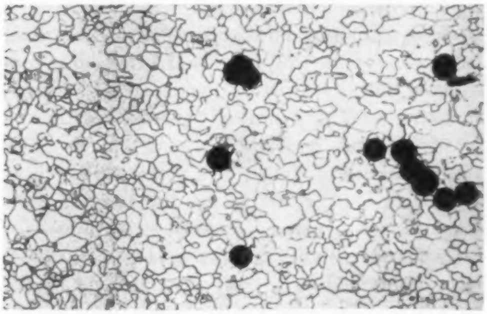


Fig. 2—Tantalum Electropolished With Electrolyte II (See Page 102) at 3 Amp. Per Sq.Cm. Spots are apparently the residue of a film produced during electropolishing at current densities below the optimum (3.5 amp. per sq.cm.). 150 ×

are apparently not caused by the polishing, but instead originate as a result of the method of production of the strip and wire used for preparing the sheet specimens. The usual way of producing columbium and tantalum is by compacting and sintering metal powders. This process leaves pores in the ingots.

In the experiments on electrolytic polishing, the pores seemed to become larger at current densities at or above that which resulted in the smoothest surfaces. Lower current densities gave smaller pore sizes, but the metal surface then became uneven and the appearance was rougher. In this condition specimens are satisfactory for ordinary microscopic examination, but not for microhardness measurements.

An attempt to explain the enlarged pores has led to the following hypothesis. The greater current density on protrusions of the anode surface results in the more rapid solution of such points. Thus, electrolytic polishing should gradually lead to a more even and smoother surface. However, where there is a pore beneath the surface, the etching rate will be dependent on the metal thickness over the pore. As this thickness is diminished, the electrical resistance increases, and metal removal at this point is slower compared with the surrounding area. Owing to the slower polishing rate, a smaller protrusion develops here. This process continues until the thin metal layer over the pore is polished through. When this has happened, the pore is filled by the electrolyte, and the edges of the pore will now play the role of protruding points and as such are exposed to higher current densities. The higher polishing rate widens the pore to an extent which is dependent on the current density.

This hypothesis may also explain the small spherical protrusions which are often developed on the metal surface during electropolishing (Fig. 1).

Surface Film

Another difficulty sometimes encountered during polishing is the formation of tiny black spots. In some experiments, they were concentrated to the center of the polished area, and clusters were sometimes visible to the naked eye. Examples of such areas are shown in Fig. 2. The spots at first seemed to have a relation to the pores already discussed, but later observations have led to the conclusion that they must be the remainder of a film produced on the metal surface during polishing when unsuitable current densities are used.

The polishing electrolyte for columbium has also been tried for anodic cleaning and brightening of specimens 0.1 mm. thick. With increasing current densities up to 1 amp. per sq.cm., an increasingly cleaner and brighter surface was observed. During electrolysis, a vigorous evolution of gas took place, and at the higher current densities a relatively thick, jelly-like film developed on the anode. Simultaneously the metal became brittle, though the brittleness seemed to be less pronounced at the higher current densities. This finding suggests that the thicker specimens used for polishing experiments might also have been embrittled, at least superficially. However, X-ray diffraction studies indicated that these samples were not oxidized as were the thin (0.1 mm.) brittle specimens which were used in the anodic cleaning and brightening investigation.

Hot Pressing Powders in England

*By ALAN BLAINEY**

Techniques for hot pressing beryllium and cermet powders are described. High pressures and temperatures are both necessary, and steel sheathing is often needed for larger parts. (H14h; Be, 6-70)

FROM 1947 to 1955, research on powder metallurgy at the United Kingdom Atomic Energy Research Establishment at Harwell was concerned with the fabrication of nuclear fuels and other materials for atomic energy purposes. During this period some work on cold compacting was done, but most of the work was devoted to improving techniques for hot pressing in a vacuum or protective atmosphere. Better heat resistant materials were used for dies and plungers. Also, duplex die molds were designed and built to take advantage of particular properties of certain materials, such as the toughness of precipitation hardened nickel-chromium alloys, and the hardness and creep resistance of cobalt-base alloys and the complex cemented carbides.

High-density materials and complex multilayer components (such as fuel elements) had to be fabricated by isotropic compacting. Flat plates, possibly of variable contour, were compacted or rolled within deformable frames. This method was also used for applying relatively high compacting pressures, beyond the limit of a simple die and plunger arrangement. Die assemblies were usually heated by radiation from electric elements (made of nickel-chromium or platinum-rhodium) which surrounded the parts. Alternatively, the powder mass was heated after partial consolidation by passing a heavy electric current through it.

Experiments in cold compacting were carried out very early in the program. The aim was to produce articles of complicated shape and high density, such as finned beryllium tubes for cladding fuel elements, spheres for radioisotope sources, refractory metal crucibles, and the like. Isotropic compacting was used to attain a reasonable density distribution in the compact. Pressure was transmitted through either a plastic organic material, such as wax or polyvinyl chloride mixtures, or a soft metal such as sodium or lead. Cavities for the powder were somewhat larger in all dimensions to allow for reduction in volume on compacting. The parts were contained in a conventional type of die having a cylindrical cavity fitted with one or two plungers which applied axial pressure. Plastic materials were shaped by casting into dies around a suitable pattern. After casting, the parts were trimmed with a sharp knife. Sodium was melted, cast, and shaped under oil; other materials needed no special protection.

In compacting finned tubes and other hollow articles, cores of plastic material assisted in obtaining the maximum density in the compacted powder mass. This method was extended to the fabrication of components with narrow internal channels. The plastic material used for transmitting pressure in such channels was nonresilient—wax mixtures, sodium or lead being used. Resilient materials, such as polyvinyl chloride compositions, produced cracks in certain components, especially in thin-walled sections, due to "spring back" on release of pressure.

When using metallic sodium to transmit pressure, care is required. Die assemblies must be designed to prevent the soft metal being squirted out of the clearance between die and plungers. If this occurs, sodium usually ignites; in any case, it endangers workers. Die-plunger clearance must be kept to a minimum (less than

*Johannesburg, Union of South Africa; sometime powder metallurgist, U. K. Atomic Energy Research Establishment, Harwell, England.

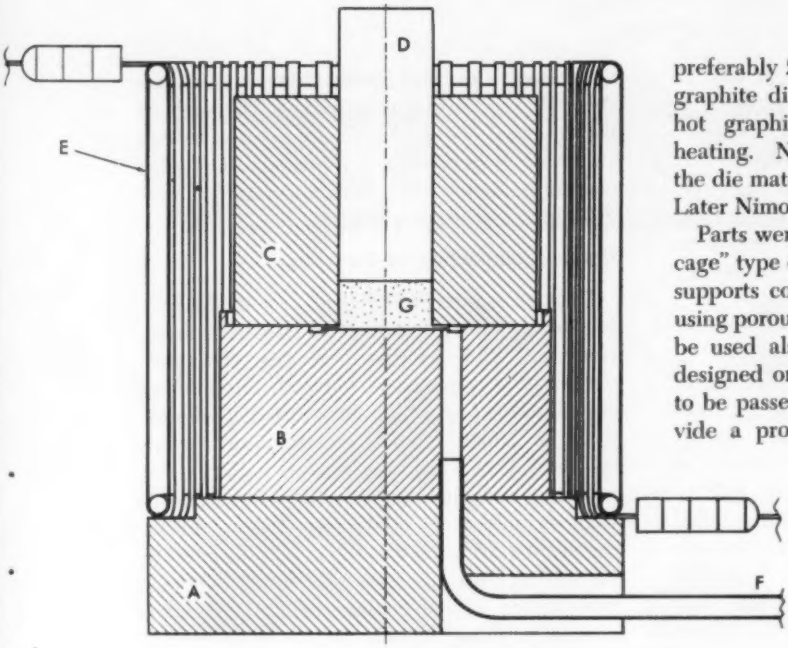


Fig. 1 — Furnace Assembly for Hot Pressing in Argon. It is made up of a base (A), a die base, mold, and plunger (B, C, and D), a heating element (E), and a supply tube for argon (F). High temperatures and pressures are needed to compress beryllium powder (G)

0.001 in.). A light coating of colloidal graphite is also applied to the components before assembly to help seal the gap and to reduce friction.

There are many problems in sintering beryllium powder. Beryllium components such as fuel element sheaths must be absolutely impervious to gases and fission products. Despite a great deal of work on the sintering of beryllium at temperatures up to 1250° C. (2300° F.) in vacuum or argon atmosphere, it was not possible to obtain fine-grained metal free from porosity. Furthermore, suitable end seals could not be formed because known methods of sealing by welding or brazing were not satisfactory. In welding, there is considerable grain growth, and the metal may crack and distort. Brazing introduces neutron absorbers, thus offsetting one of the principal advantages of beryllium. Therefore an alternative method involving hot compacting at 750 to 850° C. (1400 to 1550° F.) up to 35,000 psi. was tried.

Hot Pressing Beryllium Powder

To produce metal of practically zero porosity (suitable for nuclear fuel cladding), it was decided to use pressures of at least 10,000 psi., and preferably 20,000 to 30,000 psi. This ruled out graphite dies because gases evolved from the hot graphite contaminated the compact on heating. Nimonic 75 was originally chosen as the die material, and Nimonic 80 for plungers.* Later Nimonic 80 was used for dies as well.

Parts were heated with an external "squirrel-cage" type of nichrome element, wound on end supports covered with steatite beads, to avoid using porous refractory so that the heaters could be used also in a vacuum. The die set was designed originally to allow a stream of argon to be passed through the powder mass to provide a protective atmosphere during heating and compacting, as shown in the furnace assembly in Fig. 1. A vacuum compacting assembly was also constructed so that entrapped and adsorbed gases could be removed from the powder mass during heating prior to compacting. In this instance, the heating element was run with a low voltage to avoid flashover.

Experiments subsequently carried out showed that the properties of the hot compacted beryllium were not markedly influenced by pressing in a vacuum. Since the method was found to be rather cumbersome, it was abandoned in favor of a protective atmosphere. At first, argon was used, but it was not essential. Later a protective atmosphere was obtained by volatilizing purified paraffins (boiling range, 140 to 300° F.) with which the powder was impregnated. The liquid impregnant also helped considerably in reducing the health hazard by preventing atmospheric dispersion of the powder.

The beryllium powder for this investigation was prepared by crushing vacuum melted beryllium in a ball mill. Contaminating iron was largely removed by a magnet, the final content being 0.2 to 0.3%. Particle size varied from −36 to −200 mesh. Initially, low compacting pressures (10,000 psi.) and temperatures (1200 to 1400° F.) were used, but the metal so produced was porous. Higher pressures and temperatures were therefore required. At 20,000 psi. and 800° C. (1475° F.), a die lubricant became necessary to prevent the compact from adhering to the die walls. Colloidal graphite was applied as a dispersion in acetone

*Nimonic 75 is an 80-20 Ni-Cr alloy with small additions of titanium. Nimonic 80 contains more titanium and also aluminum for precipitation hardening.

or alcohol, dried and baked at about 150° C. (300° F.), and then polished. It also served to seal the gap between die and plunger enough to prevent air from diffusing inwardly during heating, while allowing hydrocarbon vapors to escape. Contamination by the graphite was only superficial, surface layers of beryllium carbide and graphite being easily removed by abrasion and polishing.

Detailed investigations were made of the effects of pressure, temperature, and time on the density, microstructure, and mechanical properties of compacted beryllium. It was found that beryllium of theoretical density could be produced by compacting powder of suitably graded particle sizes at 850° C. (1550° F.) with a pressure of 33,000 psi. applied for 15 min. However, repeated use of Nimonic 80 dies and plungers under these conditions caused distortion after several pressings.

At that time, the stronger Nimonic alloys were not available, so experiments were carried out using die assemblies made of titanium carbide cermets as a substitute. Originally, a 50% titanium carbide, 50% nickel composition* was used, which enabled pressures of over 30,000 psi. at 900° C. (1650° F.) to be sustained. Later, a material consisting of titanium and chromium carbides bonded with nickel-chromium alloy was used; this had better high-temperature strength and corrosion resistance. Die sets of this material could be used repeatedly for hot compacting beryllium components, including composites such as beryllium-clad uranium cylinders, to zero porosity.

*Supplied by Hard Metal Tools, Ltd., Coventry, England.

Frame Compacting of Powders

"Picture frame compacting" is a method for fabricating plates and sheet of variable contour from beryllium and other materials. The powder mass is compressed between flat backing plates (dies) of a suitable heat resisting material such as Nimonic alloy or titanium carbide cermet. This setup is contained within a surrounding deformable frame of a softer material such as mild steel or Nimonic alloy. Frame dimensions are such that the powder is laterally constrained; this prevents squeezing out during compacting. Final contour of the compacted powder is about the same as the initial internal dimensions of the frame.

In this method, the lateral restraining force results largely from friction of the frame against the backing plates. It increases during the compacting operation (due to flattening of the frame and increase in its area of contact with the backing plates) so that an approximate balance is maintained against the tendency of the powder mass to extrude.

Die blocks must be able to withstand both temperature and pressure, or they will be indented and bent. Nimonic 80 is suitable for use at 750° C. (1400° F.), and the titanium carbide-base "Turbide" alloy, or similar material, for 1000° C. (1850° F.). The latter will deform, however, if die blocks are allowed to reach this temperature throughout and pressure is maintained for considerable periods.

It is preferable to keep the blocks cool by contact with water cooled copper-beryllium alloy backing plates. Temperature distribution is improved by heating frame and contents with a heavy electric current through the whole assembly. Die blocks can be heated very rapidly, thus minimizing contamination of the powder compact during pressing

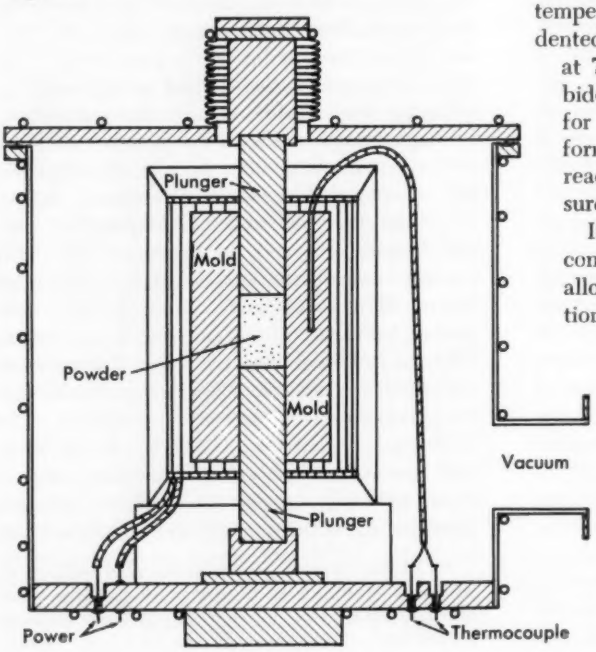


Fig. 2 – Assembly for Hot Pressing Beryllium Powder in a Vacuum. With this furnace, entrapped gases can be removed before the powder is compressed. The heating element uses a low voltage to avoid flashover

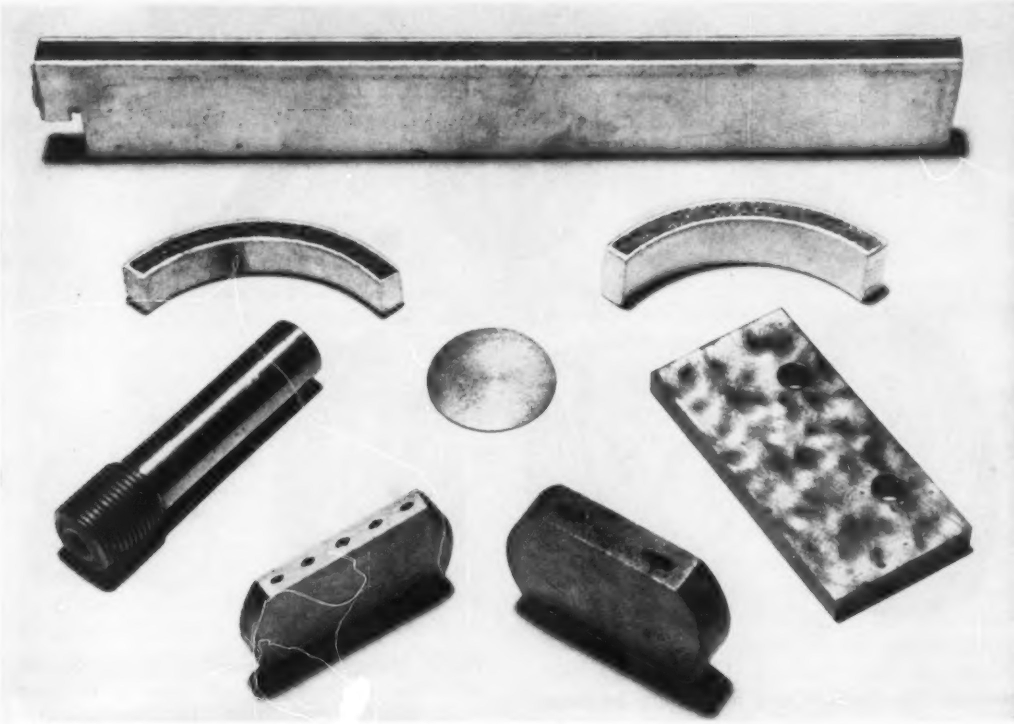


Fig. 3 – Some Components Made by Hot Pressing Powders. At the top are straight and curved strips of "boral" plate, a sandwich of aluminum sheets with a boron carbide-aluminum filler. It is used for a neutron shielding material

and overheating of the die blocks. However, care is required to avoid excessive thermal shock in the die blocks, particularly when these are of titanium carbide-base compositions. Surface cracks are readily formed, and propagate during subsequent pressing operations.

Smaller Components

When compacting smaller components, such as cylinders and spheres which require very high compacting pressures, the frame is relatively thick. In such an assembly, the lateral (radial) restraining force is balanced by hoop stresses as well as by friction of the annular frame against the die blocks. The area of contact can now be made very large (compared with the area of the peripheral surface of the bore), being approximately proportional to the square of the outside diameter. It can be shown that very high pressures can theoretically be sustained in the bore. However, pressures are limited in practice by the strength of the die blocks, which become indented when the pressure at the frame center is much more than three times the yield strength of the material. This imposes an upper limit to the pressures attainable. When using titanium carbide-base cermets at 950 to 1000° C. (1750 to 1850° F.), about 120,000 psi. may be sustained for pressings occupying a few minutes, and about 50,000 psi. for repeated long-time pressings. When compacting at 850° C. (1550° F.), the corresponding pressures would be about twice those quoted above.

In all instances, thickness of the die blocks must be at least equal to (and preferably one and a half to two times) the radius of the frame, and the diameter should be about three times the final diameter of the frame, unless constrained radially. Die blocks should be well supported by water cooled backing blocks of high-strength material. Advantage may be taken of temperature gradients in the die blocks and frame* so that higher temperatures and

*When compacting beryllium, which has a relatively high electrical conductivity, the heating current passes mainly through the compacted beryllium powder, which is thus heated to a greater extent than the steel or Nimonic 75 alloy frame.

Fig. 4 – Forgings and Stampings of Steel-Sheathed Beryllium. In front are two types of stampings, each "before" and "after" the steel sheathing has been etched away with dilute nitric acid. Note that contours are retained with ease. Forgings with half of the sheathing etched away are shown above with a machined specimen of beryllium

pressures can be sustained in the powder mass. Temperature gradients must of course be matched to the thermal shock resistance of the die block material.

Slipping Can Occur

In these methods of compacting, slippage may occur at very high pressures between the frame and die blocks because of the tenacious surface film of oxides. This results in a loss of pressure at the center. The effect can be minimized by interposing a very thin metallic layer (of aluminum, zirconium or titanium, for example) which will reduce the oxide film, form hard intermetallic compounds, and promote adhesion of the frame to the blocks. The effective frictional force now becomes very high, and shearing occurs preferentially in the frame near the die block. Pressures can be calculated from the shear strength of the frame material, but are generally not very much greater than those attained when the coefficient of friction is 0.5.

On the other hand, where the frame and contents are to be kept from sticking to the die block, the block can be coated with colloidal graphite before assembly. The coefficient of friction is thus reduced from about 0.5 to 0.1, with a corresponding reduction in the frictional restraining force. However, the hoop tensile strength now contributes a greater proportion of the total restraining force, and its value depends on the internal and external dimensions of the frame. It is commonly about 25 to 50% of the frictional component. If a frictional component is to be maintained while protecting the dies and frame from alloying with the compacted powder, the inside of the frame and the corresponding area of the die blocks only are also coated with graphite.

Metal Powders in Sheaths

Much development work was carried out on sheath extrusion and forging of beryllium flake and powder. The powder was prepared by crushing, leaching, and vacuum drying the electrolytic beryllium flake. The material was impregnated with a very small amount of volatile paraffin, and cold compacted into suitable mild steel canisters (annular in form for tube extrusion) at a pressure of about 10,000 psi. A porous graphite disk was inserted on top of the compacted powder, *(Continued on p. 178)*

Report From Israel

Failure in a Shaft

A fatigue failure suffered in service by a shaft was investigated and found to be due to improper quenching. (Q7, Q29, 2-64; ST)

*By ARIEL TAUB**

THERE was a time, and not so long ago at that, when failures of shafts, gears, and other stressed parts were blamed on "crystallization" of the steel. Nowadays, mechanics are more aware of the part that stresses play. They have even been known to concede that service conditions are often responsible for failures. Once in a while, however, a part will break after a short service life, while similar parts undergoing similar service conditions will last for years. When this happens, the unhappy possessor of the disabled machine is apt to complain bitterly about the steel. Often he is right. On the other hand, he can be wrong, too. Take the following instance.

Our laboratory received, not so long ago, a broken machine tool shaft. It was 2 ft. long and 1 in. in diameter. According to the fabricator, it was made from a normalized En 9 steel (an English grade equivalent to A.I.S.I. 1054); this we confirmed by chemical analysis. This shaft, according to our informants, failed after a few hundred hours in service. Since the manufacturer had produced a large number of similar shafts and no others failed, we decided a thorough investigation was warranted.

Our preliminary work revealed that the shaft had been heat treated (by quenching and tempering to Rockwell C-43) at one end. The fracture occurred 3 in. from the heat treated end of the shaft. Its surface displayed two zones; the outer one, due to fatigue, was characterized by radial crack propagation, while the inner zone showed the crystalline texture of a brittle fracture.

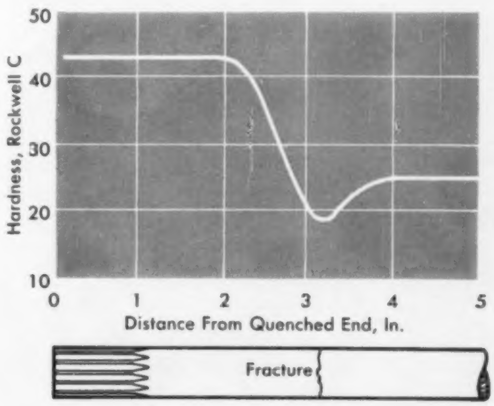
At the heat treated end, the shaft consisted of tempered martensite which was homogeneous for 2⅛ in. Beyond this, carbide particles and bainite appeared. The carbide particles gradually coarsened, and attained their largest size – 1.3 microns – 3 in. from the shaft end. This point coincided with the fracture plane. From there, the carbide particles became smaller, and gradually merged into the normalized structure 3¾ in. from the quenched end.

Hardness measurements along the shaft surface (Fig. 1) confirmed microscope findings. They averaged Rockwell C-43 to 2 in. from the quenched end. Then the hardness dropped gradually for 1⅛ in. to Rockwell C-18 (the lowest value) at the fracture plane. From here, the hardness rose to Rockwell C-25, the average hardness of the normalized portion.

These data gave us enough information to deduce the cause for breakage. The shaft, after having been machined in its normalized condition, was selectively hardened and tempered at one end. Through a flaw at one of the heat treating steps, undesirable growth of carbide particles associated with bainite occurred about 3 in. from the quenched end. This weakened the cross section, lowering the endurance limit by approximately 50%. The shaft is subjected to fatigue for 3⅜ in., whereas proper hardness is maintained only for 2 in.

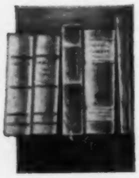
However, the fracture area was in austenitic condition before quenching, since no coarse carbides or bainite would be formed if the

Fig. 1 – Graph of Hardness With Relation to Plane. Note that fracture coincides with lowest hardness



*Senior Lecturer in Metallurgy and Acting Director, Institute of Metals, Haifa, Israel.

normalized structure were merely tempered. We feel sure, therefore, that these structural anomalies formed in the fracture area when the shaft was quenched. Either the heated section was not fully immersed, or there was alternate partial retrievement and immersion during its rapid movement in the quenching bath. The fully immersed portion of the shaft hardened to a martensitic structure, free of precipitated carbides and bainite. On subsequent heating, the martensite was tempered to Rockwell C-43. However, the finely dispersed carbide particles in the fracture area grew, upon tempering, to a resolvable size. This lowered the hardness in the fracture area to Rockwell C-18, seriously impairing the fatigue characteristics.



Book Review

Nimonic Alloys

*Reviewed by J. B. JOHNSON**

The Nimonic Alloys, by W. Betteridge, Edward Arnold (Publishers) Ltd., London, England, 1958. 332 p. 163 fig. $15.00

The literature on alloys for service at high temperatures is very extensive both in the United States and abroad. However, when anyone attempts to obtain a comprehensive review covering the development and applications of any specific alloy or group of alloys, it is necessary to consult several sources.

The author of "The Nimonic Alloys" has alleviated this situation for one of the most useful high-temperature systems, nickel-chromium.

The half-dozen or so Nimonic alloys include a wide range of analyses ranging in nickel content from 37 to 78%. Nimonic 75, 80 A, 90 and DS (Incoloy) are produced in this country and have been used for service at temperatures in the range of 1000 to 1450° F. The authors indicate higher stress-rupture properties for Nimonic 95 than for Nimonic 90. In the case of Nimonic 100, the stress-rupture strengths are comparable with such alloys as Inconel 70, Udimet 500 and René 41 in the range of temperatures of 1450 to 1600° F.

The principles governing the selection of chemical composition and metallographic structure to obtain optimum creep and stress-rupture properties are given in considerable detail for the several alloys. Much of the data on the effects of temperature time and cooling rates are taken from the original experimental work conducted by the producers of these alloys and presented conveniently in chart form. The data on high-temperature fatigue properties are especially interesting, since little data correlating stress-rupture and fatigue properties for the high-temperature alloys have been published. The data indicate a simple relationship between stress-rupture and fatigue strength independent of the temperature or time to failure.

The chapter on castings does not adequately cover the high state of development achieved in this country in precision casting nickel-chromium alloys. The higher stress-rupture properties of the cast alloys, compared to the wrought alloys, have not been exploited to the same extent in Great Britain as in the United States. No mention is made of vacuum melting or control of grain size or the successful application of castings in the critical parts of gas turbines.

The chapters dealing with fabrication and application include hot and cold working, joining, machining and inspection. The approach is quite practical. Some of the details on processing differ from those in the product manuals prepared by suppliers in this country.

The book contains much useful data presented in a comprehensive and logical manner and is worthwhile reading by metallurgists and engineers interested in the practical application of high-temperature metals.

*Retired, technical director, Aeronautical Research Laboratory, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Sponge Iron in Mexico

*By GUNTHER H. MULLER**

In the past few years, Hojalata y Lámina's plant in Monterrey has produced over 110,000 tons of sponge iron. This gaseous reduction process (termed HyL) produces material which is virtually free from residual elements and makes an excellent electric furnace charge. (D8j)

HAVING OVERCOME the usual growing pains associated with a new development, Hojalata y Lámina's gaseous reduction process (termed HyL)† has attained a maturity which entitles it to a place among the older iron ore reduction methods. Attesting to its practicality, more than 100,000 metric tons (110,000 short tons) of sponge iron produced by this process has been converted to first-quality steel products to date.

Several conditions may make the HyL process economical. It can be used where steel scrap is scarce and costly, where high-grade ores (or concentrates) and cheap natural gas are available, or where small tonnage requirements make other alternate methods unprofitable. Now proven commercially feasible, the process is expected to compete with familiar steelmaking processes in many areas of the world.

The Plant at Monterrey

In Monterrey, Mexico, a 200-ton-per-day reduction plant has been in continuous operation since late in 1957. This plant, adjacent to Hojalata y Lámina's electric furnace shop and rolling mills, is operated by Fierro Esponja S.A., an affiliated company.

Gas flow through the unit can be followed on the flow sheet shown in Fig. 1. Natural gas first passes through a preheating-recuperating coil located in the stack of the Kellogg reforming furnaces. Then, it flows through a desulphurizing drum, is mixed with steam, and is reheated in another waste heat coil. After that, it passes through the reformer tubes. Here, natural gas and steam react to produce hydrogen and carbon monoxide in the presence of a catalyst. The reforming reaction

$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$

is strongly endothermic, which makes it necessary to supply heat. Operating conditions are adjusted to produce a gas which analyzes 85% hydrogen and carbon monoxide, with 4% unconverted methane. The rest is mainly CO_2.

When the hot gas leaves the reformer, it passes through a waste heat (quench) boiler to a quench tower which cools the gas and removes excess water. The gas, now cool and dry, is then preheated, and passed through the primary reactor which holds partially reduced ore. Since more water is formed during reduction, the gas must be dried again. It flows to a second quench tower which removes this water. This cool and dry gas is reheated as before, and passed through a secondary reactor which contains fresh ore. Again, the gas is water quenched. Finally, the dry, spent reducing gas which results is used to fuel the reforming furnaces and heaters.

Reactors Have Two Sections

Reducing reactors are designed in two sections. There is a stationary flanged top head, to which the inlet gas connections remain permanently attached, and a lower flanged section which is free to move on wheels. Figure 2 shows the five reactors at the plant. At any one time, two reactors are in the primary cycle

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*Engineer, Fierro Esponja S.A., Monterrey, Mexico.

†The firm has patents and patent applications on the process in more than 20 countries, and has appointed M. W. Kellogg Co. as its exclusive worldwide licensing agent.

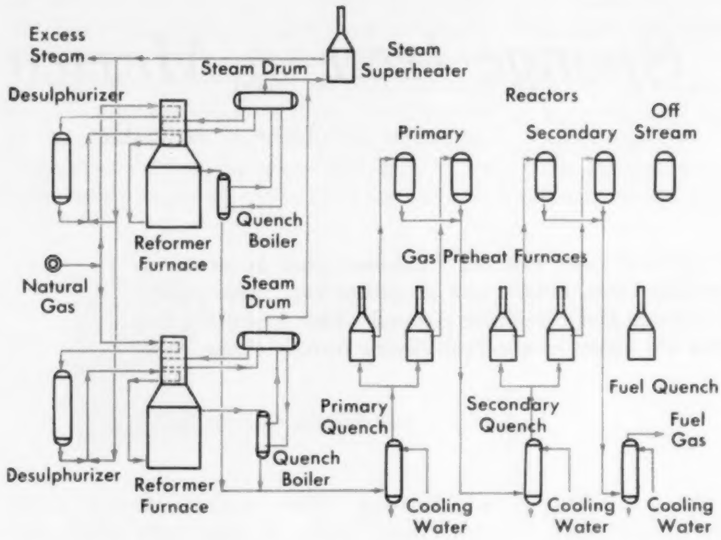


Fig. 1 – Flow Diagram for the 200-Ton-Per-Day Sponge Iron Plant

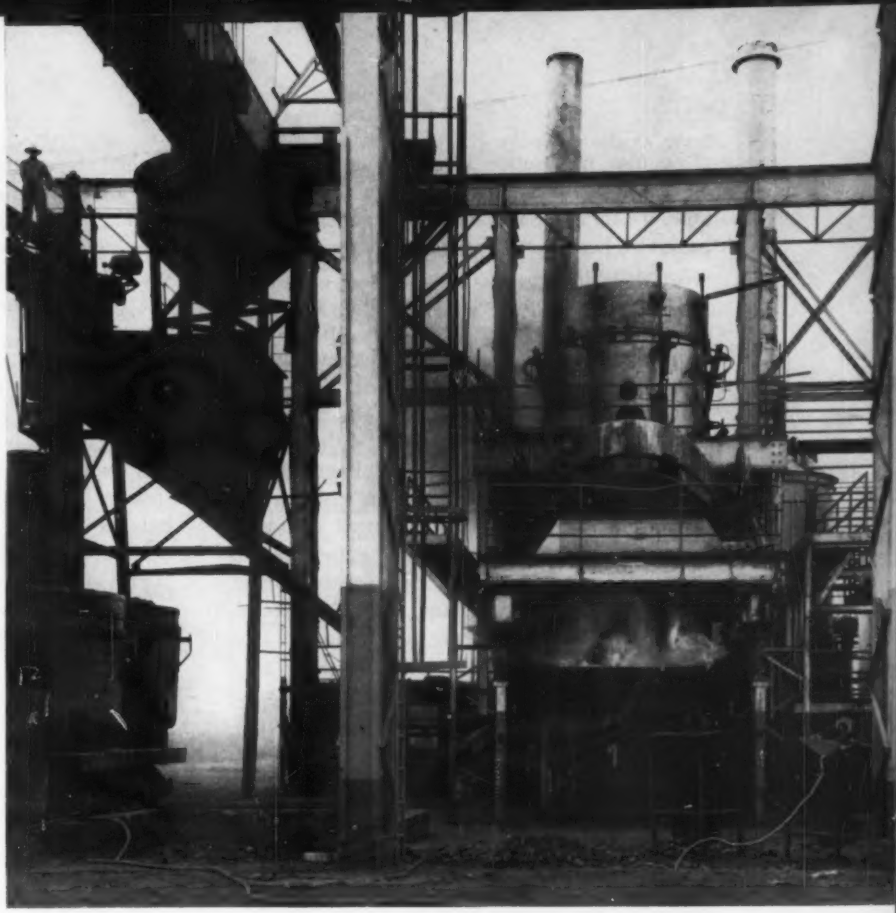
and two are in the secondary cycle. One reactor is thus always being unloaded and loaded.

As for the operation, the lower section of the reactor is charged with ore and moved under the upper section. The two sections are held together hydraulically. After purging and pressurizing with natural gas, the reactor is connected in secondary position where it receives partially used secondary gas for 2 hr. Then, the reactor is connected in primary position where the partially reduced ore is treated with fresh gas for 2 hr., at which time reduction is complete. Natural gas is passed through the reactor at the end of the primary cycle if carbon is needed in the sponge iron. At the end of the cycle, the reactor is allowed to depressurize. The lower section is freed from the top section, and moved out to the discharging position. Hot sponge iron empties into a transporting hopper as shown in Fig. 3. All valving operations are actuated from a panel in a control room.

The stepwise countercurrent principle of ore

Fig. 2 – The Reactor Area, Consisting of Five Identical Units. In the foreground are sponge iron buckets waiting to be taken to the melt shop. The two reformer furnaces are at the rear

Fig. 3 – Dumping of a Sponge Iron Charge. The lower flanged section of the reactor has been disconnected from the upper part seen behind, and has been moved out to a discharge point. There it is tilted and emptied. The sponge iron is transported to the melt shop in hoppers by railroad cars shown at the left corner of the picture. Iron ore is charged into the reactor by a hopper hanging from the overhead crane. In turn, this hopper is filled from the stationary bin fed by conveyers



and reducing gas is technically sound. It provides rich reducing gas to the ore when the reduction may be thermodynamically limited, and poorer secondary gas for the first reduction of the charge where no important equilibrium limitations exist. Reducing gas efficiencies are highly satisfactory since conversions of more than 50% are attained during the reduction on a once-through basis.

At a given reactor temperature, oxygen removal depends on the amount of gas used during a complete cycle. Ore* reduction can be carried almost to completion by increasing the time of the reduction cycle or the amount of gas flow. However, in a commercial plant, an economic balance has to be made between the cost of reducing and the cost of melting the sponge iron. In the works at Monterrey, this balance is reached when the ratio of metallic iron to total iron in the sponge is 85%. This is the figure aimed at.

Since the sponge iron never reaches its melting point, little refractory maintenance (other than to compensate for abrasion) is needed.

Melting Sponge Iron

Melting sponge iron is no more difficult than melting scrap of the same density. Just as the experienced melter will adjust his practice to conform to the physical variations of scrap, so will he do the same for sponge iron.

Up to now, all sponge iron produced by Fierro Esponja S.A. has been used in the plant of Hojalata y Lámina. The principal product is rimmed steel though some low-carbon semikilled steels have been made. Since the ore is not beneficiated, all of the gangue in the ore is present in the sponge iron. This gangue will average about 10% in the sponge, but there are indications that at times it will go higher.

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*Ores used at the Monterrey plant during normal production range from 55 to 65% in iron content. Gangue contents average 5 to 9%.

Upon request of interested companies, more than 30 different ore samples coming from mines all over the world have been tested in the Monterrey unit. Results show that any high-grade ore or concentrate (either pelletized, briquetted or extruded) gives essentially the same percent reduction as the local ore. For low-grade ores, results are rather conflicting, and no general conclusions can be drawn. However, some low-grade ores perform quite well under plant conditions.

Regular production is based on charges of 50% sponge and 50% scrap, and of 70% sponge and 30% scrap. Satisfactory experimental melts have also been made entirely from sponge without difficulties.

To obtain proper operation of a direct-arc electric furnace, regardless of the material to be melted, the electrodes should penetrate almost to the bottom of the furnace. This is so that melting may proceed from the bottom of the charge. Melting is started with a short, low-voltage arc. If too high a voltage is used, a bath will be formed too soon, submerging unmelted material, with subsequent operating troubles. If voltage is too low, penetration is needlessly slowed down. The experienced melter is aware of this, and will take precautions to obtain a proper penetration of the charge. Because of the extreme density of sponge iron, strict attention to this detail is of paramount importance.

In melting a 50% sponge iron, 50% scrap charge in a 65-ton electric furnace, electrodes can penetrate about 6 ft. of sponge without undue delay. Therefore, the furnace is charged with this in mind. A small amount of scrap (about 6 or 7 tons in the 65-ton furnace) is placed on the furnace bottom. Scrap is bulkier and will provide some voids at the bottom of the charge. They accommodate the liquid formed in penetrating the charge, and prevent premature bath formation. The sponge iron is then charged around the perimeter of the furnace so that it slopes toward the center in a crater. This will reduce the necessary depth of electrode penetration to a minimum. At the same time, furnace walls are protected from attack by acid slag during the period of maximum power input.

All the sponge iron is charged at the start. After charging, power with the proper voltage and current is connected. Once the electrodes have penetrated to the scrap in the bottom of the furnace, voltage and power input are increased to full load. When the center of the charge has fallen into the bath, the remnant of the sponge that had been placed around the walls of the furnace will flow into the bath almost continuously until it is all melted.

As stated before, the sponge iron contains all the gangue that was in the ore from which it was reduced. Consequently, a fairly large volume of silica slag will be produced. However, it is not necessary to add lime at this stage to neutralize the acid slag. Instead, the slag is flushed from the furnace immediately after melting is complete without any undue damage to the basic refractories. After this slag has been removed, burned lime is added to form the basic slag. Then the rest of the scrap is charged, and the heat finished in the conventional manner.

When melting a 70% iron, 30% scrap charge, the procedure is the same, except that only two-thirds of the sponge iron can be charged initially. It is also best to remove some slag after this two-thirds is melted. In melting 100% sponge iron, half is charged initially and the balance added in two increments. Slag is flushed after melting each increment.

Previous authors have mentioned that sponge iron melting requires more electric energy and lime than do 100% scrap charges. While this is true statistically, it is *not* true (as is implied) that these increases are needed because sponge iron is being melted. The increase in power consumption varies almost directly with the gangue content of the sponge iron currently being melted. This gangue content – and the consequent power increase – will vary widely. Increased lime consumption is due entirely to the sulphur content of the sponge iron. This means that scrap of the same sulphur content will require just as much lime. Both of these increases could be eliminated by proper treatment of the ore before reduction. The question of whether to beneficiate and desulphurize the ore, or to remove the gangue and sulphur after melting, is purely a matter of economics. Either is practicable.

At any rate, it can be said that the sponge iron currently being produced by Fierro Esponja S.A. can be instituted for scrap in any proportion for making rimmed and low-carbon steels. (Sponge iron has the added advantage of low residuals.) It also appears likely that the quality of alloy steel grades can be improved, as well.

Sponge Iron Steel for Sheets

Because Hojalata y Lámina produces steel sheet from both all-scrap heats and heats containing varying amounts of sponge iron, differences in their behavior can be easily detected. By now, enough experience has been gained to recognize that production costs are somewhat lower when steel ingots made from sponge iron heats are used. (Comparison, of course, is with ingots from all-scrap heats.) This has been true in pickling, cold rolling and finishing operations because of the lower residuals of un-

desirable elements in steel* made from sponge iron. Both types of ingots have the same hot rolling characteristics, however.

During cold rolling it has been observed that higher reductions in thickness are allowable with sheet made from sponge iron heats. Therefore, this type of steel can be cold reduced to the specified thickness in less time than required when rolling sheet made from an all-scrap heat to the same thickness. The reason: Because they have smaller amounts of residual elements, sponge iron ingots exhibit less work hardening, both in rate and in total amount, than ingots poured from all-scrap heats.

When steel from both types of ingots is annealed by the same heat treating cycle, sponge iron melts show lower hardness. Therefore, a specified maximum hardness can be obtained with shorter heat treating cycles or lower temperatures for the same cycle time. For instance, for the same annealing cycle, a 50% sponge iron steel sheet will show a hardness between Rockwell B-40 and B-50, while a scrap-made sheet will exhibit as high as Rockwell B-45 to B-55. Again, this is traceable to the relative absence of residual elements in the steel made from sponge iron.

Hojalata y Lámina's yearly production rate of about 180,000 tons of rolled product is being sold all over the country. Close cooperation with their clients has enabled their metallurgical department to follow the performance of their sheet after it leaves the mill. In nearly every instance, sponge iron sheet has provided a better quality product than obtained before with scrap-made sheet, and at a lower cost.

One client, specializing in deep drawing, can make very deep draws on sponge iron sheet without the intermediate anneal needed for steel made from 100% scrap charge. Also, fewer rejects were observed during normal production runs. Where ductility is of paramount importance, the increased hardness caused by residual elements may be serious. Recognizing this fact, Hojalata y Lámina has standardized their heats for deep drawing stock at 60 to 70% sponge iron in the charge. The same amount of sponge iron is being used for applications like galvanizing, enameling or tinning, where good surface characteristics are required. For other applications, lower sponge iron contents are being used in the heat.

It has been found that sponge iron sheet exhibits less enameling defects than scrap-made steel. This is especially true for "fishscale", a defect caused by the tendency of hydrogen in the enamel frit to diffuse into the base metal and remain in it after the enamel layer has hardened. This hydrogen concentrates at the metal-enamel interface, and creates gas pockets able to build up pressures high enough to pop up a fishscale-shaped fragment of enamel. From this, the defect gets its name.

Residual elements inhibit grain growth and uniformity, and this is the underlying cause of the better performance of sponge iron sheet during enameling. Since the rate of hydrogen diffusion depends on grain size, the larger grains in the sponge iron sheet allow hydrogen to diffuse more rapidly. This gives occluded hydrogen a better chance to leave the base metal before the enamel layer entraps it at the interface, when it solidifies. Furthermore, if the sheet is without hydrogen, fishscales will not appear later.

Another customer who makes electric resistance welded pipe has also noticed that sponge iron sheet behaves better. It is easier to form, there are less rejections in hydrostatic testing of welds, and better bend and flaring test results are experienced.

Investment and Operating Costs

Capital investment for a sponge iron plant of the HyL type will vary according to local conditions. In general, however, such an installation will cost about one half of the capital investment required for a conventional blast furnace of the same capacity. This includes coke ovens.

To produce one metric ton (1.1 short tons) of iron in an 85% reduced sponge iron in the 200-ton-per-day plant, the following raw materials are required: natural gas, 23,000 cu.ft.; electric energy, 75 kw-hr.; water, 282 cu.ft.; ore, 1.75 tons. Direct labor amounts to one man-hour, excluding maintenance, ore handling, and overhead. As a byproduct, 2500 lb. of steam at 150 psi. pressure is produced; it is being used in the plant's rolling mill.

The success achieved in the commercial operation of the 200-ton-per-day plant at Monterrey is such that *(Continued on page 192)*

*Certain metals, such as copper, chromium and nickel, retard the pickling rate when they occur in the steel base. Therefore, it is only natural to expect sponge iron sheet, bearing lower percentages of these elements, to be pickled in less time than scrap sheet. Acid attack on the base metal is also reduced so that surface quality is improved.

Vacuum Treatment of Molten Steel in Germany

*By P. J. WOODING and W. SIECKMAN**

Developed by Dortmund-Hörder Hüttenunion, this process is applicable to electric furnace, openhearth and oxygen converter production. It operates on the basic principle of forcing successive portions of liquid steel into a vacuum vessel by atmospheric pressure. A variety of controlled alloy additions can be made late in the degassing cycle. This feature, combined with a major reduction of oxygen content, leads to improved cleanliness and increased product yield. (D8m)

Six years ago, Dortmund-Hörder Hüttenunion (DHHU) was forced to develop vacuum treatment equipment because of difficulties in the production of heavy forgings. Typically, these difficulties arose from oxide inclusions and hydrogen flakes.

Chemical reactions which include a gas phase are accelerated by vacuum treatment. The reduction in pressure displaces equilibrium conditions to levels hundreds of times below normal.

Carbon, hydrogen, and oxygen are removed by these reactions. Carbon can be reduced to a minimum without an undesirable increase in oxygen contamination, and furnace refining time for low-carbon steel can be shortened. When the amount of hydrogen is lowered, conventional slow cooling practices can be decreased or eliminated. Also, reduced delivery time is permitted. Significant quantities of oxygen can be removed rapidly only if the oxygen is "free" (not in compound form). Therefore, it is desirable to degas the steel before adding elements with a high affinity for oxygen. By making such additions late in the degassing cycle, it is possible to remove most of the "free" oxygen as a gaseous deoxidation product and to flush out the hydrogen.

In addition, production-scale equipment must not interfere with the normal flow of operation. There should be no limitations in ingot size, and temperature losses must be compensated. The vacuum treatment process developed by DHHU satisfies all these requirements.

The Dortmund-Hörder Process

Figure 1 shows the latest stage of equipment development. The main components of the equipment are a degassing vessel and its nozzle, addition hoppers, an evacuation system, a heating system, and a hydraulic system for raising and lowering. Since vacuum treatment occurs in the ladle, it does not interfere with the normal tapping and pouring practices.

Now a few words on the process itself. The difference between atmospheric pressure and

*Manager, Vacuum Furnace Dept., and Metallurgist, Lectromelt Furnace Div., McGraw-Edison Co., Pittsburgh. This report was prepared from data supplied by Dortmund-Hörder Hüttenunion of Germany. Lectromelt is engineering and building this type of vacuum treatment plant for the United States, Canada and Mexico.

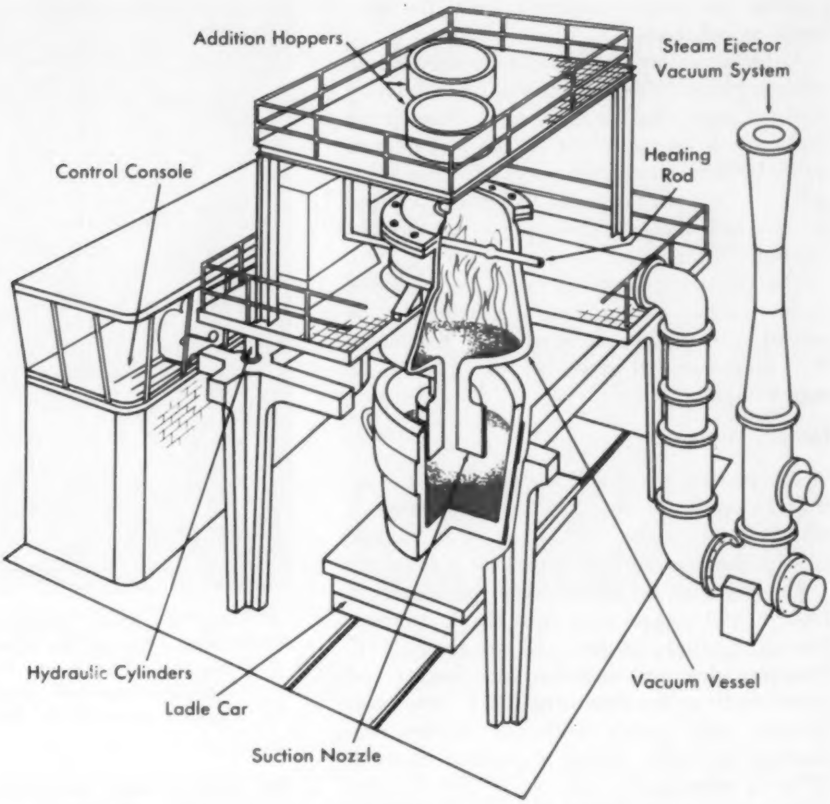

Fig. 1 – Isometric View of the Lectromelt Version of the DHHU Vacuum Treatment Unit. The graphite heating element keeps the vessel lining at around 2900° F. so that superheating before tap is not necessary

the pressure inside the evacuated vessel is enough to raise the liquid steel into the vessel. This means that the maximum difference in levels is equivalent to barometric pressure expressed as ferrostatic head, which is about 4 ft., 8 in. of molten steel.

As the unit is lowered, a portion of liquid steel rises into the degassing vessel through the nozzle. After each portion of liquid steel is degassed, it is returned to the ladle by raising the vacuum vessel. This movement, which has a stroke of 2 to 3 ft., is repeated until the ladle contents have been treated to the required degree. Each cycle takes about 30 sec. An important requirement is that the entire treatment time must be less than 15 to 20 min. The contents of the ladle need to be completely circulated three times within this period. As Fig. 2 shows, there is no significant improvement after a three-fold circulation.

Based on a given range of ladle sizes and stroke speed, this circulation requirement determines the size of the degassing vessel.*

The shape of the degassing vessel is determined by two requirements. The bath must be shallow with the largest possible area, and space must be provided for the violent turbulence which occurs during treatment. Both these factors have a direct effect on the carbon monoxide reaction and thus an indirect effect on the hydrogen removal. (Carbon monoxide flushes out hydrogen.) Also needed is a heating element to keep the vacuum vessel at around 2900° F.

The factors listed above, combined with the need to keep the heating element as short as

*Lectromelt plans to construct three basic sizes of plant: 10 to 60, 30 to 120, and 40 to 200 tons. There is no upper limit on ladle size. For the time being at least, the treatment of ladles less than 10 tons in capacity is not being considered because of increased severity of temperature losses as ladle size decreases.

possible (for greater strength), led to the illustrated vessel shape.

As for durability, the vessel refractory has an average life of 20,000 tons, and nozzle refractory lasts for approximately 5000 tons. Tests prove that there is no significant oxygen pickup from either ladle or vessel refractories. Erosion starts primarily at a joint between two bricks and can be checked through view ports on top the vacuum vessel.

The degassing vessel is raised and lowered hydraulically. If required, the ladle can be moved instead of the vacuum vessel; this makes the equipment less expensive for ladles up to approximately 50 tons.

Heating System

The heating system is used to bring the refractory inside the vessel to the temperature of molten steel before treatment. With normal ladle preheat, no furnace superheat is required.

For example, an 80-ton ladle preheated to 1500° F. will take no more than 15 min. to treat. During this time, the steel will lose about 28° F. However, degassed steel has high fluidity and pours well at temperatures 25° F. less than normal. For similar conditions without preheating the ladle, furnace superheat of about 25° F. is necessary.

Production units presently in operation in Germany all use resistance heating. A graphite rod furnishes the heating element, with the upper limit of heat input being about 700 kw. A three-phase arc heating system, now undergoing final tests, will permit considerably higher heat inputs for further process development.

Removing Oxygen

Having covered the design problems, metallurgical matters should now be considered. We start with the problem of oxygen removal. This can be achieved only by the carbon monoxide reaction. In addition to effective oxygen removal and thorough mixing, this process makes it possible to control the final chemical analysis with accuracy. Close control is possible because the oxygen content of the heat is known at all times during the treatment. This is one of the most significant advantages of the process.

The required final oxygen content may not be particularly low (as in semikilled steel, for example), but control of this content is always important. To determine the "free" oxygen content of the liquid steel, we need to know the weight of the degassed portion together with the quantity and composition of the gas removed. The weight of the steel in the vacuum vessel is easy to measure. We assume that the measured oxygen content of this steel is the same as that of the balance of the heat. This assumption is sound, provided that mixing is as complete as possible. Results have shown that mixing, which is accomplished by the kinetic energy of each portion of steel leaving the vacuum vessel, is complete.

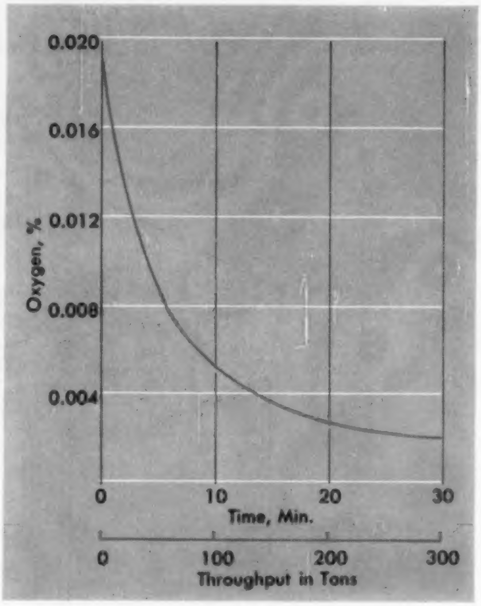

Fig. 2 – Most Reduction in Oxygen Occurs During the First 10 Min. of Vacuum Treatment. For good degassing, three-fold circulation of the molten steel in the ladle is needed

Cleanliness Is Improved

Physical properties and product yield are both improved by reducing the frequency and size of nonmetallic inclusions. This feature leads to cost savings often greater than the expense of operation. Figure 3 shows that oxide inclusions are reduced to one third of normal levels by vacuum treatment. In addition, the range of scatter in parts per million is sharply limited at both top and bottom locations. Similar results have been obtained in rolling grade steel.

For example, when a vacuum treated, rolling grade steel, containing 0.10% C maximum, was compared with a similar untreated steel of the same composition deoxidized in the normal

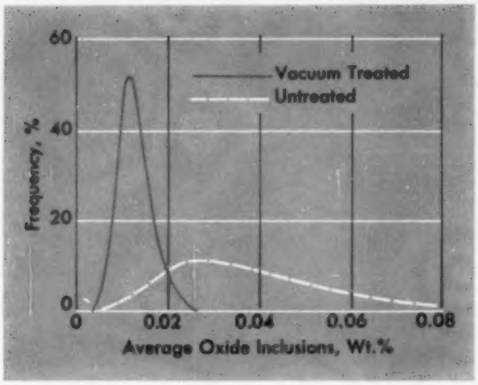

Fig 3 – Comparison of Oxide Residue in Forging Grade Ingots. Vacuum degassing has not only lowered the average weight percentage from 0.025 to 0.010, but scatter is also reduced considerably

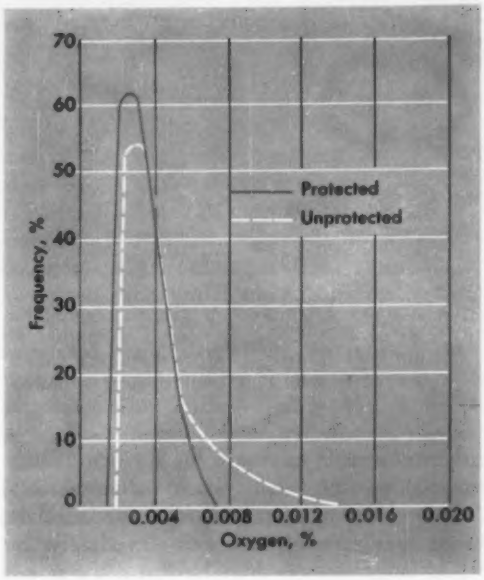

Fig. 4 – Effect of Pouring With a Protective Gas Covering. Though the average oxygen value is about the same, the protection lessens scatter considerably

way, it had a lower oxygen content (an average of 0.003% instead of 0.006%) and a narrower scatter range.

Protective Gases Are Used

During normal pouring, steel may take up further oxygen. Since this is particularly true for aluminum-killed low-carbon steels, most have been poured under a protective gas.

Figure 4 shows the effect of this practice on the oxygen content of aluminum-killed, vacuum degassed steel. Though the average oxygen value was almost the same for protected and unprotected steel, tops and bottoms of ingots cast without the protective cover sometimes contained as much as 0.015% oxygen. Conversely, ingots cast under the protective gas never contained more than 0.008% oxygen.

Most of the oxygen is removed during the degassing cycle. Therefore, very little "free" oxygen is in the metal when deoxidizing agents are added. This means that losses from oxidation are much less than during a normal deoxidizing cycle. For example, mild steel requires 0.030% Al. This is normally achieved by adding 2.5 to 3.0 lb. of aluminum per ton. However, only 0.8 to 1.2 lb. per ton is needed if the oxygen is removed before aluminum is added. Clearly, this improves the cleanliness of the degassed material and reduces the cost of additions.

In vacuum degassed steels, alloying elements such as silicon, which react exothermically when added to molten steel, can be introduced into the degassing vessel without any difficulty. Large additions are made by stages, and the number of subsequent fillings is slightly increased to mix the heat adequately.

If large quantities of endothermic elements are added, either they must be introduced in the furnace to avoid a great drop in temperature, or more superheating is required before tapping. The choice is dependent upon the behavior of the alloying additions under vacuum. For example, nickel, molybdenum, and chromium (to a certain extent) can be added in the furnace without difficulties.

Effect of Chromium

Considerable quantities of spring steel, silicomanganese steel and steels containing up to 1% chromium for forged and rolled products have been treated. The degree of purity of vacuum treated steel is illustrated by Fig. 5 which shows oxide residues, chromium oxide inclusions, and the hydrogen content of a steel containing 0.70% chromium. Because chromium was added in the furnace, it was possible to pour the melt at the usual temperature. Essentially, the graph shows that hydrogen can be reduced in spite of the presence of chromium.

Chromium lowers the activity of oxygen in liquid steel. This action impedes evolution of

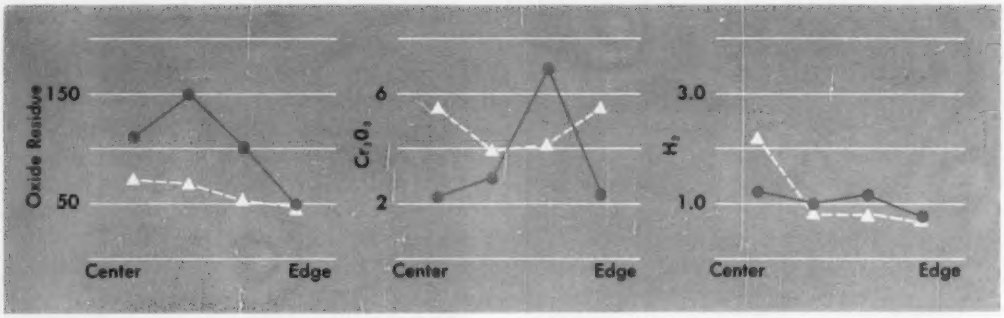

Fig. 5 – From Left to Right, These Diagrams Show Oxide Residue, Chromium Oxide, and Hydrogen, All in Ppm. All values are determined on one vacuum degassed ingot, and are taken from center to edge at both top (dashed line) and bottom (solid line) locations. This ingot weighed 45 tons, and contained 0.45% C and 0.70% Cr

carbon monoxide in any of the high-chromium grades. However, because more carbon monoxide is evolved at the low pressures in effect during vacuum treatment, a major reduction of Cr_2O_3 is possible.

Figure 6 is based on tests carried out by DHHU in a vacuum induction furnace simulating conditions in the production-scale unit. Oxygen contents always obtained after vacuum treatment are below the upper curve. This means a decrease in Cr_2O_3 content (even in higher chromium grades) within 1 to 2 min. (These experimental heats contained 0.01 to 0.02% C. In higher carbon grades, reduction should be even more rapid.)

Effect on Mechanical Properties

One consequence of the improvement in cleanliness is better machinability. This was proved by tests carried out at the Technische Hochschule Aachen, in which the machinability of vacuum steel was compared with that of untreated steel. The results showed that normal cutting speeds were increased about 15%. An increase in the edge life of the cutting tool was obtianed, in some instances as much as 90%.

Transverse properties are related to types of nonmetallic inclusions generally known as stringers. As a result of the improvement in cleanliness affected by this process, transverse properties closely approach longitudinal values.

Removal of Hydrogen

As is well known, determination of hydrogen contents in molten steel is difficult. With several established methods to choose from, DHHU selected the one which was, in its opinion, the most reliable. Hydrogen and oxygen sampling is accomplished by the immersion mold method of Speith and vom Ende and analysis by vacuum fusion at approximately 3270° F. Using these methods, DHHU finds an average hydrogen content after vacuum treatment of 2.0 ppm. In the as-forged condition, the hydrogen content of vacuum treated material averaged 1.0 ppm. as shown in Fig. 7.

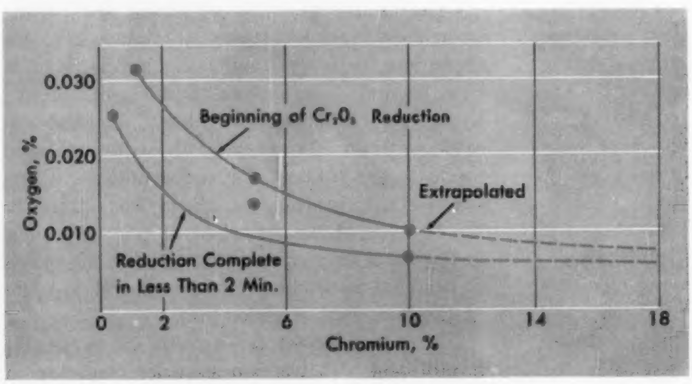

Fig. 6 – Reduction of Cr_2O_3 in Vacuum Melted Heat. These values were obtained from tests made with a vacuum induction furnace. Conditions simulated those in a vacuum treatment unit

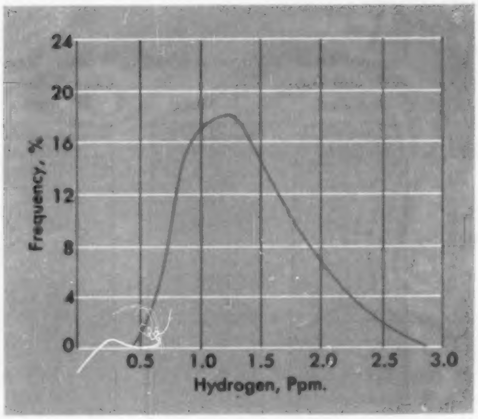

Fig. 7 – Hydrogen Content in Forging Grade Ingots Produced From Vacuum Treated Steel

Increased pump capacity in DHHU's recently developed plant and further improvements in the shape of the vacuum vessel resulted in lower hydrogen values. For example, samples from the degassed molten metal showed an average value of 1.6 ppm. of hydrogen.

Chemical determination of the hydrogen content, using the tin fusion method at approximately 2100° F., gave equivalent figures after allowing for analytic tolerance.

The process obtains the full benefit of degassing until late in the treatment, which means better hydrogen removal. Known reasons are: lower hydrogen partial pressure, diffusion of the gases soluble in the liquid steel into the carbon-monoxide bubble (in which their partial pressure is very low), and larger effective surface for degassing. This is illustrated by Fig. 8, which shows that the bulk of the hydrogen is washed out with the carbon monoxide. After addition of ferrosilicon, less carbon monoxide forms, with a corresponding drop in hydrogen removal.

Due to its relatively low diffusion rate, nitrogen needs a considerably longer time to be eliminated from the bath. However, the reduc-

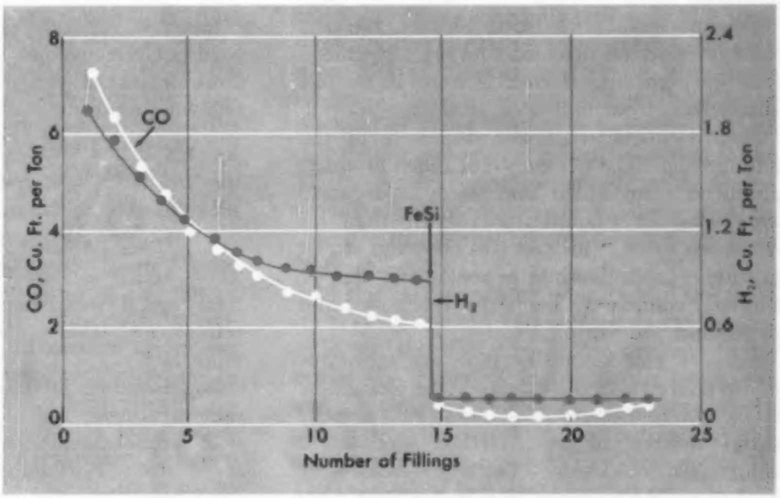

Fig. 8 – Hydrogen Is Removed With Carbon Monoxide Evolution. When ferrosilicon is added, the remaining oxygen combines with the silicon, no more carbon monoxide is formed, and the hydrogen is no longer flushed out of the melt

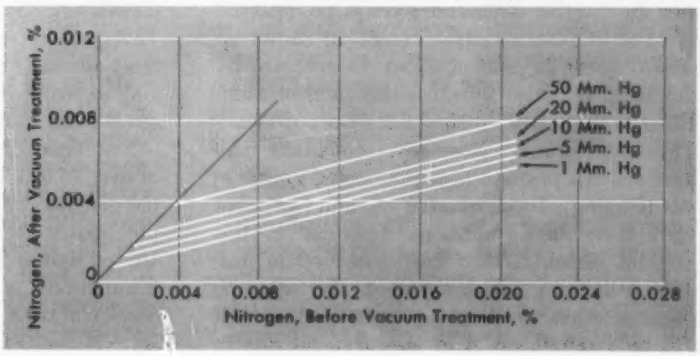

Fig. 9 – Conditions For Nitrogen Removal in Degassing. Nitrogen requires more time for elimination than either hydrogen or oxygen

tion is dependent on the initial content. For example, the average nitrogen content of openhearth steel is about 0.004% and this value is reduced by 15 to 20% during treatment. On the other hand, the relatively high nitrogen content of some electric furnace steels can be brought down to openhearth values, as shown by Fig. 9.

In aging resistant steels which require low nitrogen, either aluminum (in killed steels) or boron or vanadium (in semikilled steels) can be added very accurately toward the end of the degassing cycle to reduce the nitrogen content.

Vacuum treatment not only improves steel quality, but there are advantages obtained during processing and machining. In one typical test, more sound forgings were produced from vacuum treated melts as compared with those from untreated steel. This was true for both ingots and blooms. In each instance, the percentage of sound machined forgings produced from vacuum treated steel is from 10 to 12% higher than from untreated steel.

Improvements were also achieved in the rolling mills. The net output of rolled products produced from killed and vacuum degassed steel was, for example, 5% higher than for untreated steel. This fact was observed at first in forgings, semifinished products and shapes, and later confirmed when slabs were rolled into plates and wide strip.

Primary and secondary pipe are inevitable in top poured slab ingots. Since the cleanliness of vacuum treated steel resulted in substantially better welding of pipe, DHHU was led to eliminate the sinkhead. Vacuum treated steel, poured in this manner, was rolled into coils and sheets. No laminations could be detected in spite of severe tests. Figure 10 shows an improvement in yield of about 8% achieved by this method. Also shown is the yield of semikilled vacuum treated steel for a deep drawing wide strip grade. Normally, semikilled steel used for this purpose is contaminated and subject to aging. By combining vacuum treatment with subsequent addition of boron in the vacuum vessel, DHHU has succeeded in producing a clean, nonaging steel. If for some reason the hot top must be retained, there will still be a significant yield improvement due to the welding of the secondary pipe and better ingot surface.

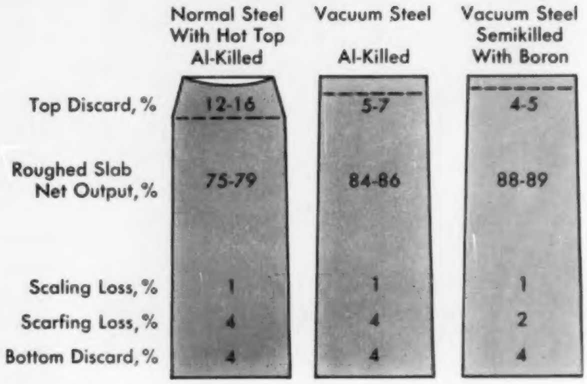

Fig. 10 – Vacuum Treatment Improves Product Yield in Low-Carbon Steel for Welded Pipe. Improved cleanliness makes this possible

Operating Costs

Based on several years of operating experience in Germany, and using average American units of cost, Lectromelt has established the following figures:

Annual Tonnage	Cost per Ton
50,000	$5.00
100,000	3.50
200,000	3.00
500,000	2.75

These figures include five-year depreciation of total capital cost, average steel plant overhead, refractories, labor, power, steam, water and other factors.

Summarizing, DHHU has developed a vacuum treatment unit which does not interfere with normal operations and is independent of ingot size. Furthermore, the unit produces steel which is excellent in terms of improved cleanliness, hydrogen reduction, and yield. This process makes it possible to select the most advantageous time for alloying additions, and to avoid detrimental superheating of the openhearth bath.

Five years of development, and a production of over 75,000 tons, have led to a process which has general application and considerable further potential. Acceptance has been rapid in the United States. Work has already begun on two installations: a 40 to 200-ton unit for Crucible Steel Co. of America and a 10 to 60-ton unit for National Forge Co.

Training Metallurgists in the U.S.S.R.

*By IAN G. SLATER**

Russia has 26 institutes devoted to the teaching of metallurgical and allied curricula. The faculties are of the highest caliber; pay is up to ten times that of a mechanic. Applicants for entrance number many times the available openings, and students know that their future depends on successful scholarship. (A3)

At the invitation of the Ministry of Higher Education in Moscow, a small delegation of senior staff of the College of Advanced Technology of Birmingham, England, recently visited Russia to survey their higher technological education and industry. Naturally the resulting impressions are limited by the duration and scope of our tour, but the objective was to examine the magnitude and caliber of the teaching and training under the Russian system and to discuss the salient features with our opposite numbers in the U.S.S.R.

This was indeed a unique occasion, for we in this country knew but little of the details of the Russian system and we naturally welcomed this exchange of information and views on a matter which is vital to the future of civilization. We also visited a number of research institutes and factories to learn something of the integration of technology between them and the schools. Travels took us to Moscow, to Sverdlovsk in the Urals, and to Dnepropetrovsk and Zaporozhye in the Southern Ukraine.

A few statistics are desirable at the outset, if only to emphasize the magnitude of the Russian effort. Of the 220 million population, some 40 million are undergoing some form of education. Of these, two million are at institutes of higher education. The latter are capped by 33 universities; then come 27 polytechnics, 32 mechanical engineering and allied institutes, 26 metallurgical, mining, geological, petroleum and allied institutes, together with institutes concerned with other applied sciences in the field of chemistry, physics, electrical engineering, foods, building, transport and a host of other specialties amounting to over 200 institutes. Other institutes concerned with such specialties as agriculture, forestry, economics, medicine, physical culture and teaching bring the total to about 725. It is to be emphasized that these institutes (in contradistinction to the 33 universities) deal essentially with undergraduate and postgraduate teaching and research with students ranging in age from 18 to 26 or so.

In Russia, compulsory education of the child starts at the age of 7 and continues until the age of 14, and therafter, for selected students, to the age of 17. These are known as the seven-year and the ten-year schools and an avowed objective apparently is to increase continuously the numbers permitted to remain to the age of 17. The curriculum laid down for this primary and secondary education is reasonably well standardized and there is no significant effort to afford specialization in the more advanced years. The number of hours of school work per week is rather greater than ours in the Western world.

The Educational Ladder

The diagram (Fig. 1) is a simplified version of the Soviet educational ladder. Our limited time permitted us to study only the higher edu-

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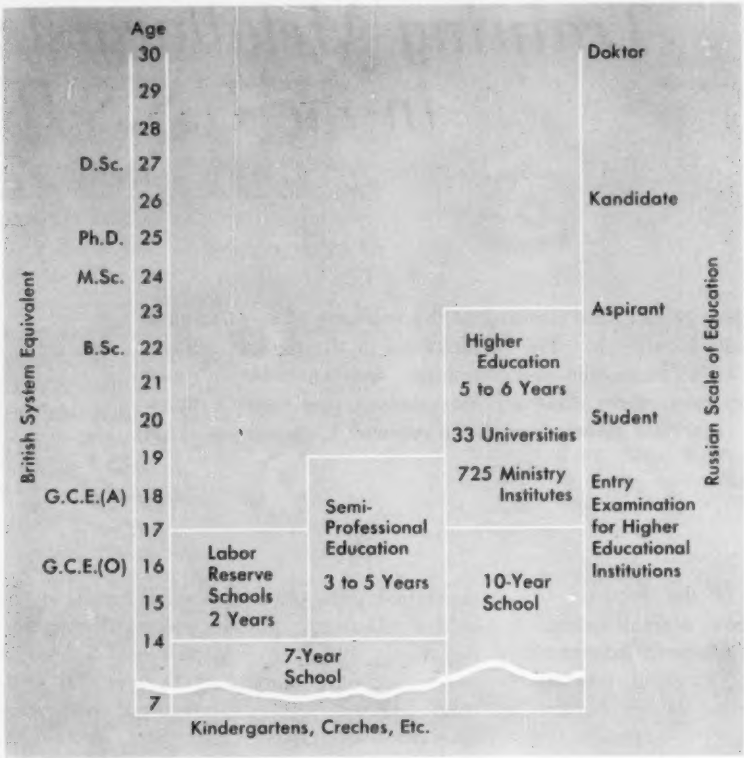


Fig. 1 – Soviet Education Ladder. Under the British system equivalent, the abbreviation G.C.E. (O) Signifies General Certificate of Education (ordinary level) and G.C.A. (A) signifies the certificate awarded at the advanced level

cation establishments but we were told that over half a million students enter the labor reserve schools each year and a similar number enter semiprofessional schools.

Higher education starts in the post-seventeenth year and competition for a place in one or another of the institutions is truly formidable. At Moscow University, for example, there have sometimes been more than ten applicants for each place; other institutions may be rather less popular but without exception applications are several times the number of vacancies. After all, the Russian student is made well aware from his or her earliest age that the path to success is closely associated with academic progress. There is no doubt as to the serious way in which youth bends to the task. This way of life and mental approach to future responsibilities is indeed a most notable feature of the Russian scene. On reaching 17 years of age, the 2% or so of the brightest students are awarded a gold medal with their certificate of maturity and these selected few may enter the higher institution without further examination. The next 2 or 3%, in order of merit, get a silver medal and are required to pass an examination in perhaps one subject only, such as mathematics. Less fortunate students, and they are of course the majority, must take a comprehensive examination in five subjects; for example, at the Mendeleev Chemical Technological Institute in Moscow the subjects are mathematics, physics, chemistry, Russian and one foreign language.

There seems to be a growing insistence on some industrial experience before the ten-year student enters the higher institution. Thus, special concessions may be given to those who have worked two years in a factory and the standard for acceptance, in academic performance, lowered very considerably. Undoubtedly, such "practical" information has substantial advantages in a technological training but there may be other reasons unknown to us of a more philosophical nature which prompt this plan. Technology freely attracts both sexes in Russia; thus quite 20% of the metallurgists or mechanical engineers are women while chemistry might yield 60%. Wastage of students during the five or six years of the course may amount to 10 to 15%, mainly at the end of the first year.

Turning again to the diagram in Fig. 1, it

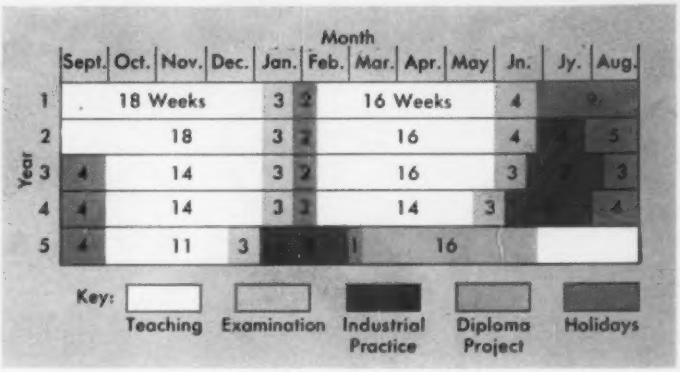


Fig. 2 – Timetable of the Kalinin Institute for Nonferrous Metals

will be noted that courses in higher education may last from five to six years before the student "graduates". The academic year normally covers the period from the first of September to the first of July, with a break of two weeks in January. The working week is a six-day one. This certainly means that the total hours per annum in class and laboratory are substantially more than those of the Western world, and the content of the course much greater than that required for a first degree over here, whether it be the three-year Bachelor of Science or the four-year technical diploma or engineering degree. The timetable over a typical Russian five-year course is shown in Fig. 2.

Specialization in General Metallurgy

Metallurgy is one of no less than 16 technologies which are offered in the Russian higher educational scheme, and in each of these 16 there is a large number of specializations. The 15 specializations classified under the general heading of metallurgy are:

1. Metallurgy of ferrous metals
   a. Metallurgy of pig iron
   b. Metallurgy of steel
   c. Electrometallurgy of steel and ferrous alloys
2. Metallurgy of nonferrous metals
3. Metallurgical furnaces
4. Foundry production
   a. Ferrous metals and alloys
   b. Nonferrous metals and alloys
5. Physico-chemical examination of metallurgical processes
   a. Metallurgy of ferrous metals
   b. Metallurgy of nonferrous metals
   c. Metallurgy of rare metals
   d. Powder metallurgy
   e. Corrosion and protection of metals
6. Physics of metals
7. Pressure treatment of metals
   a. Rolling and drawing
   b. Forging and stamping

This great array of specialization is indeed formidable; we have nothing like it in the Western world. It is right to emphasize, however, that much of the first two years of the formal five-year course is taken up with the basic sciences – mathematics, chemistry and physics, together with quite a heavy load of descriptive geometry and drawing. Professional subjects are first encountered toward the end of the second year and their scope is wide, and more or less common for all the 15 varieties listed above. Real specialization appears no sooner than the fourth year.

In the final year, the student undertakes "diploma work" in the form of a quite substantial research project. The efforts we saw seemed to be of really excellent caliber and the project often had a close link with some current industrial problem requiring cooperation with local industry. The task often involved process evaluation and design studies and finally emerged in the form of a set of beautifully executed drawings supplemented with a neatly written report or thesis of 100 pages or so. We were proudly shown this work by several enthusiastic students who obviously were burning much midnight oil in its execution to the exclusion of all other possible distractions.

The content of any particular course is reasonably well standardized throughout the country. By way of illustration, it is useful to diagram two examples which bring out features mentioned in previous paragraphs and which emphasize the range of subjects covered. (See Table I.)

In addition to full-time students, many of the

Table I – Content of Two Five-Year Courses in Metallurgy
(Numbers Indicate Hours Per Week)

Years	Metallography and Heat Treatment	Common Content	Nonferrous Foundry Production
I and II	Physical training 2.	Marxism-Leninism 4, Foreign language 2, Higher mathematics 4½, Physics 3½, Inorganic chemistry (1st yr.) 5, Chemical analysis (2nd yr.) 5, Physical chemistry (2nd yr.) 3, Drawing 3, Theoretical mechanics 2, Strength of materials (2nd yr.) 4, Crystallography (1st yr.) 1	Hydraulics (2nd yr.) 2, Workshop (1st yr.) 4
III	Furnace technology 3, Fuels and refractories 1½, Theory of metallurgical processes 2½, General metallurgy 6, Metallography 5, Radiography 3, Powder metallurgy 2	Political economy 2½, Theory of machines 5, Electro-technics 4½	Physical chemistry 2, Thermotechnics 21, Furnaces 5, Metallurgical theory 6, Metal working 5, Foundry production 2½
IV	Mechanical handling 1, Thermal energetics of factories 3, Pressure treatment of metals 3, Theory of heat treatment 4½, Economics of metallurgical industry 2, Physics of metals 2½	Political economy 2, Welding 2, Radiography 2	Analysis 1½, Heat treatment 2, Automatics 2, Construction 1½, Planning 2, History of technics 2, Foundry production theory 3, Casting 5, Molding 5
V	Strength of materials 1½, Foundry production 3, Automation 2½	Electrotechnology 2½, Organization and planning 2, Research project and thesis (balance)	Pressure treatment of metals 4, Safety techniques 2, Molding 2

institutes receive evening and correspondence students. Time did not permit us to assess these, but we understood that the courses take a rather longer time, and that successful students receive the same rewards as their full-time colleagues. The correspondence students (who may live some distance away – and Russia is a very large country) attend each month for a day or two for oral instruction and to meet their tutors. Numbers involved in these part-time studies are probably far less in proportion to those in Great Britain where many thousands of our youth tread the hard way in part-time day-release or evening courses. Some indication of numbers is shown in Table II, which also quotes data for research students in a number of the institutes we visited.

Research Work in the Institutions

Postgraduate work may lead in three years to the higher degree of "Docent" or "Kandidate" and thereafter in another three years to the "Doktor" status. Not inconsiderable numbers travel this path and they are indeed the elite of academic attainment. This research work is part and parcel of the teaching environment and obviously is of inestimable value in providing the right atmosphere of academic well-being and technological drive. In these establishments the members of the teaching staff also engage in some research work. Furthermore, quite a few independent research workers from local industry use the facilities. Equipment seemed to be installed on a most generous scale and we were told that industry readily provides new equipment, materials and encouragement.

Laboratory facilities merit a special note: We found quite substantial differences in different institutes; for example, the University in Moscow is particularly well equipped while some other institutes had very mediocre materials with which to work. However, we were very firmly advised by the Russians that they were thoroughly aware of the deficiencies, and that it was only a matter of time to get them corrected. These establishments have a high priority in the building program and there was much visible evidence of reconstruction and substantial expansion.

In addition to the more usual laboratory apparatus, some institutes had a fair amount of pilot plant – for example, at Dnepropetrovsk a one-ton steel converter, using oxygen, had been installed with substantial rolling mills alongside.

If criticism can be raised, it may be that the Russian student spends less time in the laboratory than his contemporary over here. Possibly the press of sheer numbers of students is the cause of this. Often a team of students using any one piece of apparatus would be much larger than we would consider desirable. In passing, it should also be mentioned that some institutes were running a double shift, so that lecture rooms and laboratories were active from early morning until late evening.

Table II – Students at Institutes Visited

Location and Establishment	Number of Students		
	Full-Time	Evening and Correspondence	Post-Graduate (Research)
Moscow			
University	15,000*	—	200
Mendeleev Chemical Technological Institute	3,800	300	100
Bauman Engineering Institute	10,000	—	300
Metallurgical Institute	4,000	—	—
Sverdlovsk			
The Urals State Polytechnic	10,000†	8,000	650
Dnepropetrovsk			
Chemical Technological Institute	3,700	400	120
Metallurgical Institute	3,000	1,800	400

*1400 in the Chemistry Department.
†2000 in the Metallurgy Department.

Having disposed, all too briefly, of the organization of the higher educational system, I should now comment on the human material involved. First, the teacher – for he or she is indeed a vital factor in the search for enlightenment and knowledge. Perhaps one of our most profound discoveries in Russia was the fact that there is just no shortage of teachers of the highest caliber. The solution to the acute problems, so obvious in this country, has been quickly realized and rectified by the Russians in the extremely simple (and reliable) expedient of according the right pay, conditions and status for the job. It is certainly a great joy to meet not only a contented staff but also men and women of intellectual quality with imagination and drive. These teachers are not in any way overloaded by routine work but have time for reflection and research. The full-time teaching staff is augmented by "visiting professors" who are the senior members of one of the many research institutes associated with the particular applied science concerned. Many members of the full-time teaching staff have research interests either in their own institutes or in a nearby research institute which provide them, not only with the personal satisfaction of doing useful work, but also not unsubstantial financial rewards. Perhaps in this difficult task of "learning", one might comment that the Russians seem to organize and discipline their students far too much and to mother them in such a way that students do not develop fully the senses of discrimination, judgment and outlook which we like to think our English students possess.

Fig. 3 – The Great Bell in the Kremlin

The Student Body

A second comment would be that the Russian has been well conditioned throughout his scholarship to hard work with limited distraction and with the clear view that academic success will reap rewards as well as fulfill his duties expected by the all-powerful *(Continued on p. 193)*

Explosive Forming in Canada

*By H. P. TARDIF**

Canadian firms are increasing their research efforts in explosive forming. Aircraft companies report successful forming of skins and engine parts. The investigation of metal gathering – explosive forming which results in the walls of the formed part being thicker than the original workpiece – has continued, and welding by explosive impact is being explored. (G-general, K6; NM-k34)

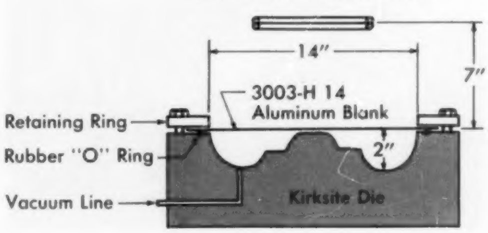
THE EFFORT devoted to high-energy-rate metal forming in the United States during recent years has created great interest in Canada, and work along this line has been initiated both in research and development. Although the effort spent in Canada to date is only a small fraction of that spent in the United States, some progress is being made in this field and the highlights are reported here.

The Explosives Laboratories of Canadian Industries Ltd. have recently installed facilities for underwater explosive forming of metals. Two setups have been used so far. A tank 18 in. in diameter and containing 2 ft. of water is used in forming small test specimens about 6 × 6 in. A larger tank 8 × 12 ft. with a maximum depth of about 5 ft. of water is also available to form larger pieces with heavier charges, perhaps up to ½ lb. of high explosive.

One research project at the physical metallurgy division, mines branch of the Department of Mines and Technical Surveys concerns fundamental studies of the ductility and formability of metals under impulsive loading. Metal sheets are deep drawn in a small pressure vessel by a free-forming operation. Variables such as amount of charge, pressure, type of metal, and thickness of blank are being studied. The pressure vessel used is completely leak-proof and consequently noiseless. This offers an advantage when explosive forming is to be carried out indoors. Other aspects of this research project now underway in Ottawa also include the forming of shapes in closed dies.

In the industrial field, many firms, especially those in the aircraft industry, have been active in experimenting with high-energy-rate forming. At Avro Aircraft Ltd., Toronto, a cartridge-actuated free-floating piston has been used for piercing and dimpling sheets of titanium and other alloys for aircraft skins. In another firm, Bristol Aero-Industries Ltd., Winnipeg, components have been made of 3003-H 14 aluminum with the arrangement shown in Fig. 1. Forming is carried out under water by placing the assembly in a 50-gal. tank. The water head above the blank is about 2 ft. Concrete and kirksite dies have been employed. With concrete some crumbling occurs at sharp corners over which the metal was drawn. Concrete dies with steel inserts at these points should be satisfactory for production runs. Kirksite dies proved entirely satisfactory. When making the configuration

Fig. 1 – Arrangement Used for Explosive Forming Test Parts at Bristol Aero-Industries Ltd. With this shape, high vacuum is required in the die cavity to prevent spring back



*Head, Materials Laboratory, Canadian Armament Research and Development Establishment, Valcartier, Quebec.

shown in Fig. 1, a very high vacuum in the die cavity was necessary to prevent spring back of the part after the explosion.

One of the most active firms in this field is Orenda Engines Ltd. of Toronto. Various shapes have been formed including air duct panels, cone frustums, fan blades, annular rings and turbine blades.

In forming air duct panels, the die, sheet metal blank, and explosives are immersed in 4 ft. of water in a cylindrical steel tank 6 ft. in diameter and 6 ft. deep. Most work was done with Types 321 and AM 350 stainless steels in aluminum dies. The largest air duct panel, which has an area of 5 sq.ft., is pictured in Fig. 2. Grooves in the panel are 0.120 in. deep.

Principal difficulty in this work was sealing off the water from the die. Various techniques were used to prevent the water from penetrating the die cavity between die and blank. Applications of silicone rubber or glyptol and linen tape or vinyl tape around the edge of contact between metal and die proved successful. Another method which consisted of evacuating a polyethylene-mylar bag placed around the die and blank produced excellent results. The charge was Primacord containing 50 grains of explosive per ft. Tests indicate that with the setup conditions previously described, about 6 to 10 ft. of Primacord was necessary per square foot of 0.030-in. thick Type 321 stainless steel to form the air duct panels. Some work hardening occurs, the Vickers hardness increasing from about 165 to 250.

At the Canadian Armament Research and Development Establishment, work was continued on the forming of conical and hemispherical shapes by metal gathering (*Metal Progress*, September 1959). In this method, the free blank is accelerated toward the bottom of the die without being retained by a blank holder. This process, which results in thickening rather than thinning of the blank during forming, has been applied to larger and more complicated conical shapes such as those shown in Fig. 3. Forming is now carried out under water, and variables such as amount of charge and stand-off distance can be changed to produce different shapes. Cones with cylindrical stems of various lengths have already been formed from copper, stainless steel, and aluminum sheet. It is expected that step-like and bell-shaped cones could also be obtained.

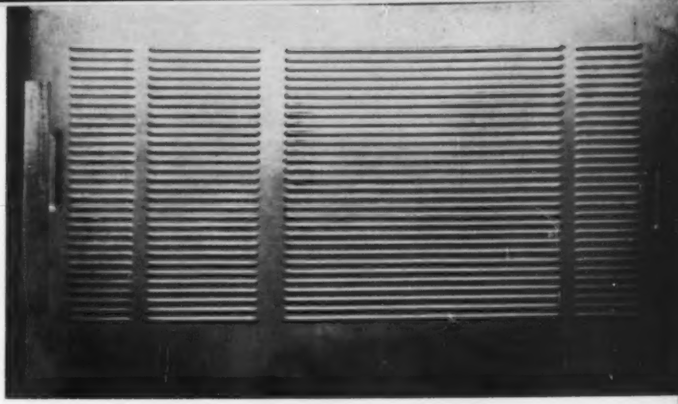


Fig. 2 – Corrugated Air Duct Panel of Type 321 Stainless Steel 0.030 In. Thick Made by Explosive Forming at Orenda Engines Ltd. Panels like this have also been made of AM 350 stainless steel, titanium and aluminum

The mechanics of the deformation process during forming have been studied by means of a grid scribed at the surface of the blank and by hardness and thickness measurements. Typical results obtained from a cone (Fig. 3 right) are given in Fig. 4.

On fully formed cones having a stem, the wall thickness of the cone is greater than that of the original blank all the way from the base to the stem. Deformation of the grid indicates that the metal stretches along the side of the cone. However, the metal gathering effect is great enough to compensate for stretching and provides an over-all increase in wall thickness.

Some experiments have been carried out on the welding of dissimilar materials by means of explosive pressures. Thin plates of 1100-0 aluminum, mild steel, stainless steel and galvanized iron were placed in contact with brass

Fig. 3 – Conical Copper Shapes Produced by Explosive Forming in Water With Various Charges and Stand-Off Distances. The walls of the cones are thicker than those of the original workpiece because the starting blank was not clamped or restrained over the die cavity

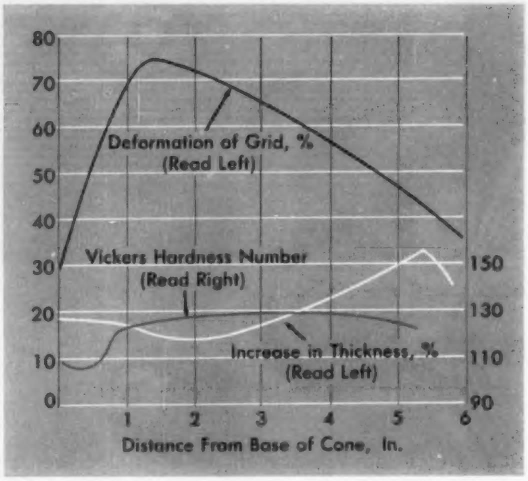


Fig. 4 — Hardness and Deformation Measurements Along Fully Formed Copper Cone Shown in Fig. 3, Right. The metal has stretched during explosive forming as indicated by deformation of grid lines which were scribed on the starting blank, but thickness has increased. Starting blank was 0.183 in. thick, with Vickers pyramid hardness of 65

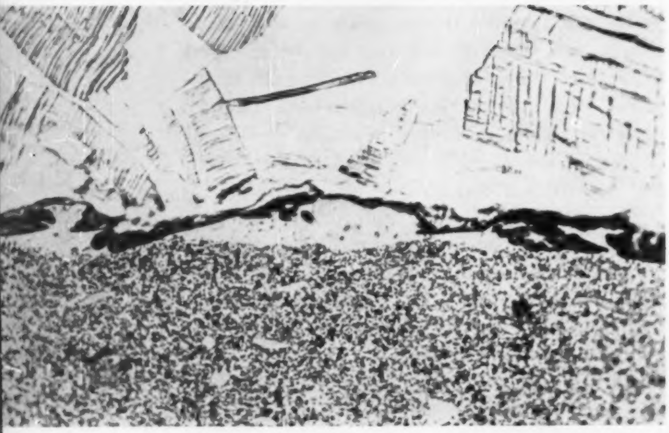
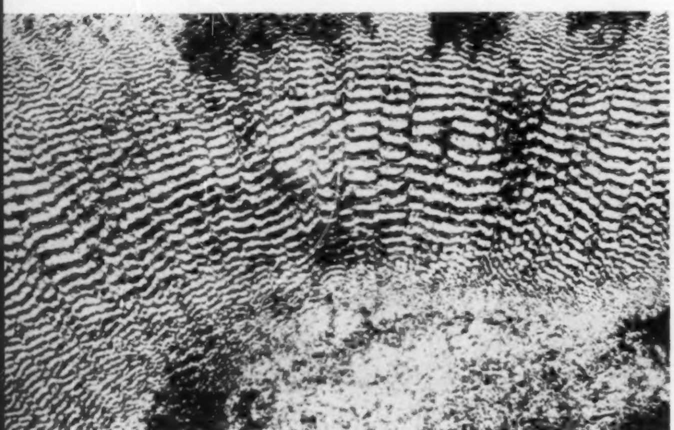


Fig. 5 — Interface Between Brass (Top) and Aluminum (Bottom) Sheets Which Were Bonded by Detonating an Explosive Charge Above Them. 1500 ×

Fig. 6 — Fine Ripples Typical of Those Produced at the Interface of Sheets Bonded by Explosive Impact. 30 ×



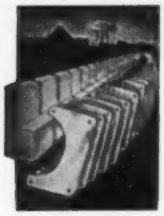
or copper plates 0.125 in. thick and 3.5 in. in diameter. A small pellet of explosive was placed 3 in. above the assembly and detonated. Bonding is not very uniform and occurs in patches. Joined by this technique, steel and copper sheets could be pulled apart although there was evidence of bonding and formation of a new compound at the interface. With aluminum on copper, it was impossible to separate the sheets because the aluminum tore around the bonded areas. This indicates that the shear stress of the bond in this case was very high. Stainless steel and brass couples gave a shear stress of 17,000 psi.

The hardness of both components of each couple was also increased appreciably during the explosive bonding. Thus stainless steel increased in hardness by 40 points Vickers.

Microscopic examination revealed new phases at the couple interfaces. In the steel-brass couple this phase could only be revealed when the specimen was etched with a copper etching reagent. When the specimen was etched with a copper etch (ammonium hydroxide and hydrogen peroxide), only a line could be seen at the interface between the two metals. When an aluminum etch (hydrofluoric acid) was superposed, a new phase or phases appeared which apparently formed from aluminum — the metal of lowest melting point of the two. In the aluminum-brass couple the new phase formed at the expense of the aluminum (Fig. 5).

The interesting feature of these tests was the presence of a layer of alloyed metal at the weld interface which indicates the existence of a real metallurgical bond between the dissimilar materials. There was some evidence that this layer forms at the expense of the material having the lowest melting point of the two materials in the couple.

When the joint could be pulled apart, the bonded patches showed fine ripple marks (Fig. 6). The cause of this rippling phenomenon and its effect on bonding and bond strength are being investigated. Better surface preparation and the use of plane shock waves will probably result in better bonds.



Short Runs

Celluloid Replicas Aid Study of Metal Fractures

*By KONRAD KORNFELD**

Macrofractography has proved to be a useful laboratory tool because the fracture appearance often points to the cause of failure. Microfractography has also contributed to the solution of several problems, but owing to its tediousness it has not become popular in spite of the efforts of those working in this field. To overcome the difficulty of specimen illumination and the laborious positioning of the

*Ottawa, Ont., Canada

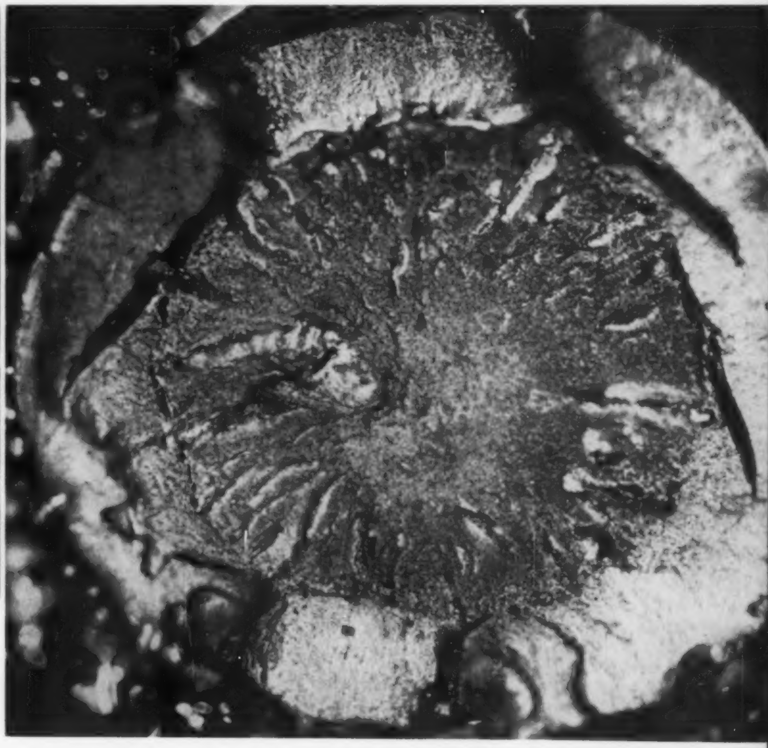


Fig. 1 – View of Cup-Dome Fracture in a Steel Specimen. Above, actual surface; 20 ×. Right, celluloid replica slightly squeezed between two glass slides; 25 ×, transient light

fractures under the microscope, a replica technique was developed. As in most replica-making, some manual skill is required, but with very simple tools and a little experience, good replicas can be readily produced.

In the technique described here, replicas of fractures are made from a solution of celluloid (cellulose nitrate) in methyl acetate which bonds the fracture to a celluloid strip. When the solution dries, the strip, which now contains a reproduction of the fracture, can be peeled from the specimen. The viscosity of the solution affects the results very little, but it is advisable to select thinner liquid (1 g. celluloid in 25 cc. methyl acetate) for uniform fractures and a viscous solution (1:10) for making deep replicas.

Any hand press may serve the purpose of making replicas. A flat piece of rubber about ¾ in. thick (a piece of an automobile tire is satisfactory) is put on the press table and covered with clean paper on which a strip of celluloid of the required size is positioned. The celluloid should be 0.002 to 0.006 in. thick. The thick sheet is preferred for large, irregular fractures. Thinner celluloid absorbs less light and flattens more readily but is more difficult to strip.

When the "rubber die" and celluloid sheet are ready, the methyl acetate solution is applied to the fracture and the sample is quickly positioned (within 1 to 5 sec.), fracture surface down, on the celluloid. Sufficient pressure is applied to cause a small indentation in the rubber. Pressure should be maintained for about 2 to 3 min. until the celluloid strip has adhered to the fracture. Once it is removed from the press, the replica will harden in about 5 min. It can then be gently stripped from the fracture surface. If the strip is wrinkled, it can be flattened by taping to a flat surface and heating it with a hot air stream until gentle stretching removes the wrinkles. The other end of the strip should also be taped to the flat surface as the replica cools.

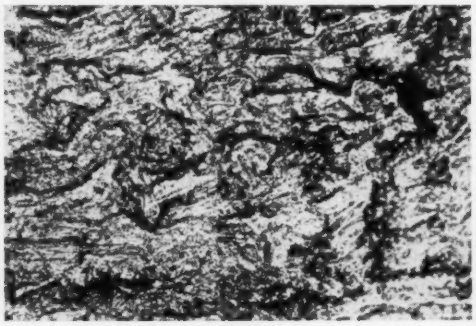
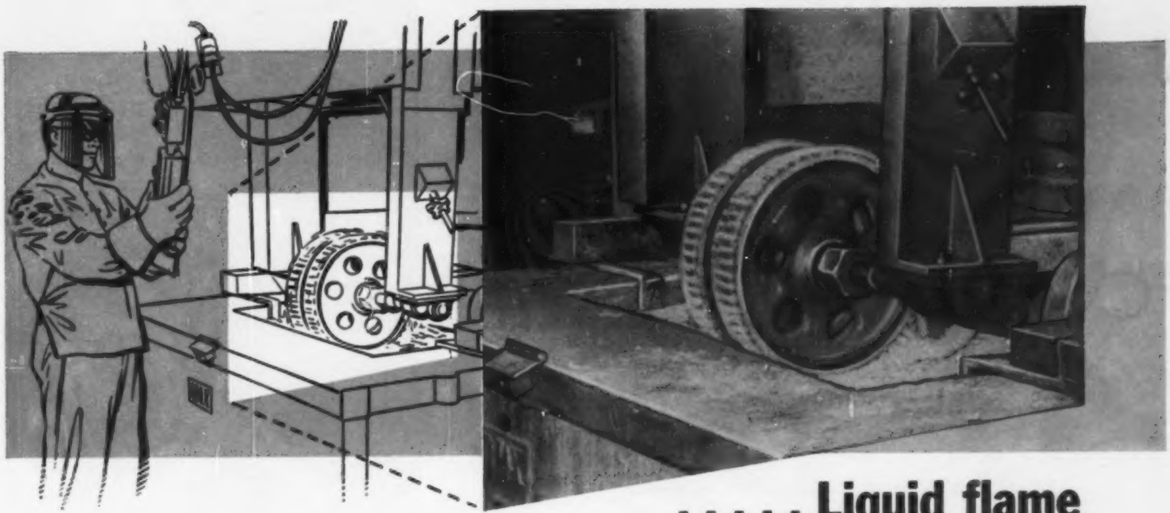


Fig. 2 – Photographs of Replicas Taken From Fracture Surface of a 2025 Aluminum Forging Which Failed in Fatigue. Above, 50 ×; right, 1000 ×

A cover glass may help to flatten the replica, but the surface which reproduces the fracture should be directed toward the microscope objective. The cover glass on the objective side may deform the high spots on the replica.

Figures 1 and 2 show the results obtained by this method.



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Readers Vote Yes on Metric System

DEARBORN, MICH.

With respect to the article "Should We Go to the Metric System?" (*Metal Progress*, August 1959), I should like to report the results of an informal poll taken in the metallurgy department of the Ford Motor Co. Scientific Laboratory. The metallurgists polled are all engaged in basic research and would be expected to favor the metric system. The actual vote was 20 to 1 in favor of the metric system. The reasons for favoring the metric system are stated in the article, and I believe that one cannot dispute that we *should* go to the metric system.

This obviously leaves unanswered the questions of whether the change *could* be made and how to go about it. The same metallurgists who agreed on the superiority of the metric system were sharply divided on these questions. Six were convinced that the change was not possible, while six others believed it possible, but stated that the cost was too high and that it would not occur. Nine thought the change to the metric system could and would occur in America. It was recognized by all that industry would resist the change because of its cost. Without a doubt, it would be expensive and industry would be reluctant to change even though convinced of the metric system's superiority. Industry must be convinced that the change will pay off in dollars.

In spite of this major obstacle, I believe that the metric system will gradually come into general use. The rapid pace of our advancing technology will necessitate the use of metric units as the gap between research and industry narrows and the delay time between laboratory and production shortens. Several suggestions were made in the course of our discussions as to how this gradual conversion could be accelerated. These are:

1. Begin to teach the metric system in grade schools so that everyone becomes familiar with the system. Most students are not introduced to the system until they reach high school.
2. Ask the various technical societies such as A.S.M. to assist by requiring the use of metric units and degrees Celsius (centigrade) in all of their publications and technical papers.
3. Begin now to build metric machine tools and other equipment to replace old equipment. (This is probably easier said than done, but a start must be made.)
4. Try to convince the military to build their new equipment using metric units.

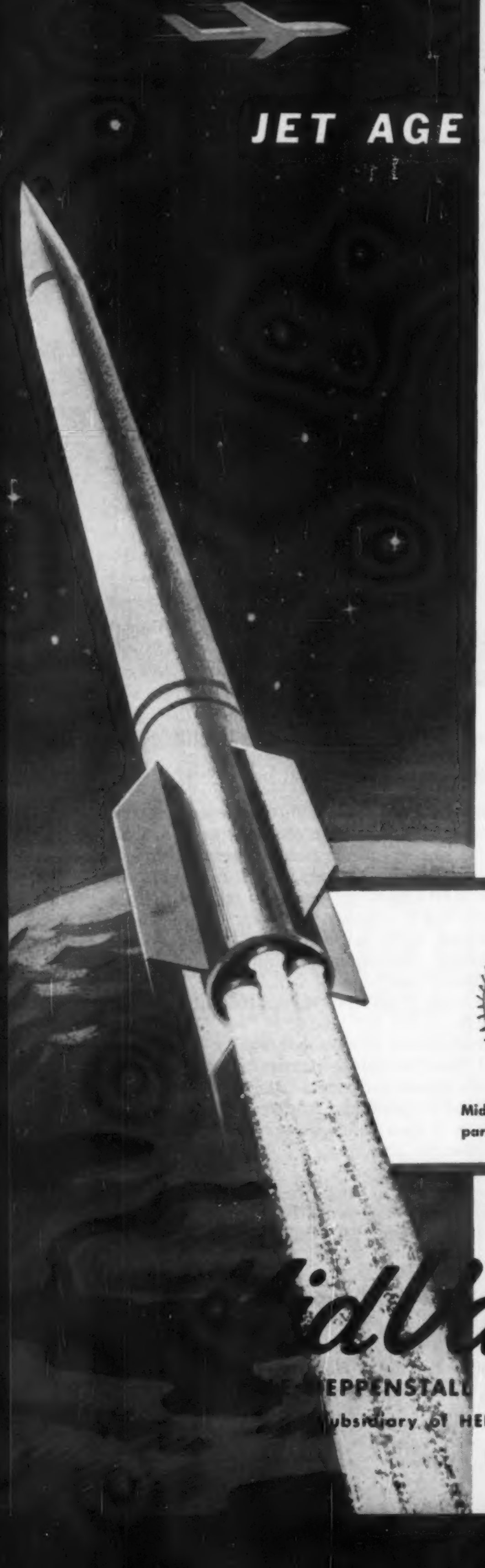
Any system of measurement constitutes a basic language not only for engineers and scientists, but for the entire society. The fact that the metric system is easier to learn and use than our present cumbersome one should not be overlooked. It seems to me that its adoption would make more persons conversant with mathematical calculations.

WILLIAM A. GOERING
Research Metallurgist
Scientific Laboratory
Ford Motor Co.

BIRMINGHAM, MICH.

Concerning "Critical Points" in the August issue just received – the suggestion to adopt the metric system calls to mind an apocryphal yarn concerning Sir Joseph Whitworth, which was told me many years back by my father; the events are supposed to have happened a century or so ago.

It seems Sir Joseph had just nicely established his system of screw threads, to his own satisfaction at least. He had developed some pretty accurate end-measuring machines, when he was approached by a group suggesting inches be abandoned and metric lengths substituted. He was given a long list of reasons why this was a most noble notion. Among them, the statement was made that the meter had been intended to be some decimal fraction of the length of the gradient of the meridian of longitude through Paris, although later information indicated it was a bit "off" in this respect. Sir Joseph is supposed to have listened politely while the sales talk was made – and



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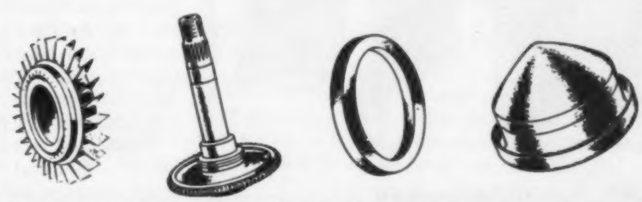

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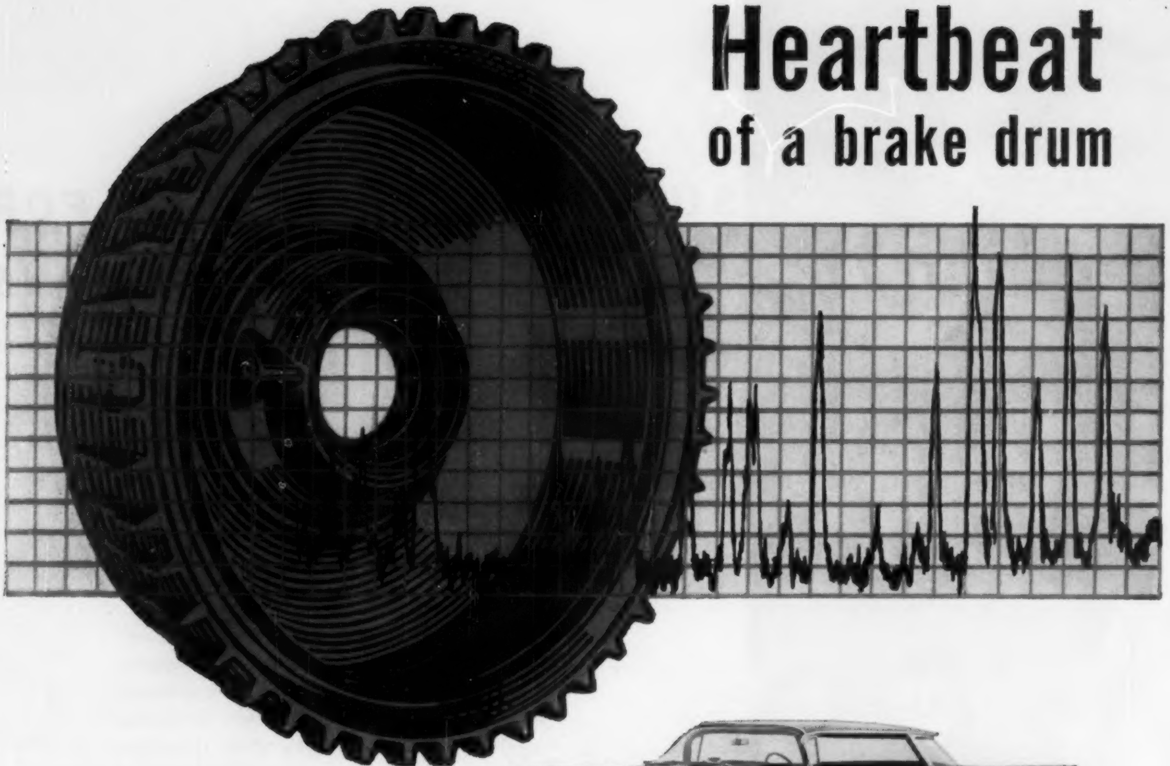

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to the surprise of all expressed willingness to go along with the scheme, *provided one minor adjustment could be agreed upon.* Encouraged, the visitors asked the nature of the adjustment; Sir Joseph replied, "If you gentlemen will make your meter just equal to forty of my inches, we are in business" – or the Victorian equivalent of this Americanism.

Looking back a hundred-odd years, methinks maybe the old boy wasn't so far off after all!

ROLAND V. HUTCHINSON
Retired
Engineering Staff
General Motors Corp.

EASTLAKE, OHIO

Should we go to the metric system? Yes, by all means! Of course, I realize that this is easier said than done, but let me elaborate some of my ideas.

Since everyone agrees that the metric system is more convenient, the only obstacle remaining (and a big one indeed) is the practical transition in science, industry and everyday life. The main resistance will originate from habit. All the familiar quantities will look so totally unfamiliar when expressed in the new units. For example: Would you feel (without consulting a conversion table) that an outside temperature of 33° C. is hot, cold, or pleasant? It would take an average person who is willing to make the change several years to acquire the feeling for these new figures. An unwilling person would never quite make it. But that should not be a deterrent. For the next generation will grow up with the new system, and in about two generations the old system will have been all but forgotten. The process can be compared to learning a new language. The more proficient you become the less you "translate" from the old language.

Now for some practical suggestions. The most expensive area for the changeover is certainly industry (tools, screws and nuts as mentioned in your article). The first step, in my opinion should be a simple restatement of all dimensions, quantities, and so forth in the metric system. For example a ⅛-in. screw should forthwith be called a 3.18-mm. screw with the accuracy car-

Correspondence . . .

ried to as many digits as necessary for the job. This would involve no physical changes (no new tools) whatsoever, but it would result in a gradual mental readjustment. As new machinery is designed and old tools wear out, I can envision their replacement by parts with more convenient dimensions. This would necessitate a double inventory in many branches of industry for years to come, but I believe this would not constitute an insurmountable obstacle. It would certainly be less expensive than a sudden and complete changeover (which could never be complete). With regard to charts and the like, the conversion could be done fairly quickly since it involves mostly paper. In cases where a direct recalibration is impossible or impractical, conversion tables could be used until the instrument in question is worn out.

In everyday life, a compromise could be reached by defining 1 gal. as equal to 4 l., 1 lb. equal to ½ kg. and 1 in. equal to 2½ cm. (40 in. to 1 m.) The inaccuracies introduced by these definitions would make no difference in, say, dressmaking or cake baking, and the public might accept the new system more willingly if they had these simple correlations.

In closing I want to mention (what you may have guessed already) that as a native German I have been brought up with the metric system and am therefore strongly prejudiced in its favor. However, after having lived in this country for over seven years, I can also testify that it is possible to get completely used to a new system. The process of adjustment is quick if the new system is used exclusively. Though it will be slow if a whole people has to be converted, in my opinion it will not be impossible.

Ursula E. Wolff
Metallurgist

Oakland, Calif.

I cast my vote in favor of the proposed changeover to the metric system. Although my prime forte and background is in structural engineering, a field which will be very greatly affected by such a changeover, the long range benefits far out-

Correspondence . . .

weigh present disadvantages and encumbrances resulting from the changeover.

In this fast shrinking world, engineering talents cannot be kept continually within our borders. My company, for example, is very carefully studying foreign operations in areas where the metric system is now standard. All of our people who are active in these areas will have to work with the metric system. It is better to start making the transition prior to the time of necessity, so that we may become familiar with and accustomed to relative values for all the many physical properties we depend upon in our engineering activities. The English system, being familiar to us, can be used as a quick check upon our detailed calculations.

In making the transition to another system of units, we will have to develop a new system or series of values for these mental checks. Yesterday or last year is the best time to start. Since today and tomorrow are the best substitutes for yesterday and last year, let us get underway with the program *now*.

WROYCE W. STARNES
Staff Sales Engineer
Kaiser Aluminum & Chemical Sales, Inc.

LOS ANGELES

It seems to me that one can plausibly contend that the weights and measures we use are infinitely more charming, more practical and more amusing than the metric system. One might also contend that habit is a force too strong to break and for this reason we should not change. However, I cannot follow your line of reasoning that to change over could not be done piecemeal and that serious reasons of hardware would make a changeover difficult.

You mention the fastener industry first, and say that every screw, nut, and so forth is measured in the English system. As long as we use inches as a measure of length, this is bound to be true; but what difference does it make if a No. 8 screw has a diameter of 4.16 mm. instead of 0.164 in.? Or a sixpenny nail a diameter of 2.87 mm. instead of 11½ gage (0.113 in.)? And is it more confusing to find that a ½-in. pipe

Correspondence . . .

has a diameter of 21.3 mm. instead of 0.840 in.?

You go on to mention machine tools. They are full of ball bearings. Ball bearings have always been made to metric dimensions, and most of them are so made and listed. They are full of holes drilled to numbered sizes, which are as odd in inches as in millimeters.

You claim that the changeover could not be done piecemeal. Why not? Why couldn't we change from Fahrenheit to centigrade and leave inches alone? Who cares if ball bearings are metric or not? Would metric wire gages be more confusing than the multitude of gages we now have (U.S.S., W&M, Stub's Iron, Stub's Steel, Music Wire and others)? How about the various tapers used on machine tools?

The conversion would involve changes in names and changes in things. The only *things* to change would be scale graduations and conversion tables. Names could be changed as desired, or not changed at all.

Perhaps this is the real reason we cannot change – it is much easier to change things than to change names. In summer we start our work an hour earlier, but we cannot say that office hours are from 7:00 to 4:00; we must keep the names from 8:00 to 5:00 and change our watches. Similarly, it is probably easier to say that a ball bearing has a bore of 1.1811 in. than to call it an even 30 mm.

In other words, you are probably right, our collection of customs won't be changed, but the reasons you give for not changing do not seem cogent to this reader.

H. O. Fuchs
President
Metal Improvement Equipment Co.

A Metallurgical Celebration in Germany

Stuttgart, Germany

The celebration of the 25th anniversary of Max Planck Institute's Metallforschung and the simultaneous dedication of the new laboratory

for the study of "special" and reactor metals took place late in November and included four sessions with a score or more of interesting lectures. Most of the latter were by staff members although several were by guests from other countries. Much of the subject matter concerned reactor metallurgy, as was fitting for the new laboratory.

I would like, rather, to say something of the aspects of this *Jubilaum* which were novel to a visiting American. The opening session was particularly symbolic. After a resume of the 25-year history of the institute by its director, Werner Köster, Otto Hahn paid tribute to the past and spoke of the future plans. (Dr. Hahn, it will be remembered, is one of the men who correctly interpreted Fermi's experiments in the 1930's and so pointed the way to power from nuclear fission. He is now president of Max Planck Gesellschaft, which supervises many scientific institutes.) This prepared the way for the "Key Ceremony" and the formal tender of the new building to its future tenants.

The Key Ceremony was opened, as is traditional, by the architect who, key in hand, made a neat little speech. He then passed the key to President Hahn, who noted the significance of the occasion and passed the key into the strong and experienced hand of Professor Köster as head of Metallforschung. Professor Köster expressed appreciation for the support of the various agencies which had financed the new department, and, turning to the director of the Special Metals Laboratory, he said, "Now, dear friend Gebhardt, I turn to you," and handed him the key. In that way Dr. Gebhardt was set up in business officially and traditionally!

Between the Friday and Saturday sessions we enjoyed a delightful interlude, a *Festabend* at the banquet hall of the Kursall at Bad Cannstatt. It was truly a festival evening with music, dancing, good food and interesting company. There were also two special events:

At one time the regular orchestra left and a new one took its place and started playing a minuet. Then a side door opened and a stately procession of a dozen couples came in. They were dressed in the style of Goethe's day for a royal appearance – men in white wigs with

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Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Link-Belt Company, Indianapolis 6
National Mall. & Steel Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

Correspondence . . .

knee-length trousers and court dress for the ladies. Upon looking twice, we saw that it was led by none other than Prof. Köster and his charming daughter. The ensuing minuet was a beautiful dance, so the onlookers would have nothing less than a repeat performance.

The second special event was another surprise – an informal and illustrated history of the MPI in Stuttgart which was put on with great gusto and good humor by Fritz Förster. A feature was the use of dual photographs showing "Then" and "Now"; frequently it seemed as though someone knew that a companion photograph would be taken 25 years later. Many ASMembers became acquainted with vivacious Dr. Förster during his tours with the World Metallurgical Conferences and they will know what a jolly good show he put on.

In complimenting Prof. Köster on the successful *Jubilaum,* I told him in English that it was to be expected from an "old pro". He wanted to know what an "old pro" was, and I told him that it was an informal title earned only after years of experience and an extended demonstration of outstanding professional competence. Never was the title more justly conferred. While the *Jubilaum* honored notable people and their contributions, and featured a new era in metallurgical science, it is best summed up as a well deserved tribute to one man – Werner Köster.

Sam L. Hoyt
Consultant
European Research Office
U. S. Department of the Army

PERSONAL MENTION

Paul F. Ziegler

PAUL F. ZIEGLER has been named technical director of Johnston & Funk Metallurgical Corp., Huntsville, Ala. His new responsibilities include supervision of all research and development programs being carried out at the J & F Huntsville plant (where the company recently set up its headquarters, formerly in Wooster, Ohio). He will also oversee factory operations, but his primary concern will be process development and application of molybdenum, tungsten, tantalum, titanium, zirconium and other special metals in a wide variety of mill shapes.

A graduate of the University of Illinois, he was a metallurgical engineer with Fansteel Metallurgical Corp. in North Chicago, Ill., for the past seven years.

Peter Zouraeff is now a forming engineer with the engineering services division of Reynolds Metals Co. He was formerly with the company's research and production operations in Richmond, Va., and Phoenix, Ariz.

Henry T. Magnussen, for many years an official of the Lindberg Engineering Co. and the Lindberg Steel Treating Co., Chicago, has been named advisor to N. A. Olsen, director of the metalworking equipment division of the Business and Defense Services Administration. Mr. Magnussen, who recently resigned from Lindberg Steel Treating Co. as vice-president and director of engineering after 26 years of service, will be on temporary duty without compensation from the government.

James H. Hinman is now manager of aluminum industrial sales for Revere Copper and Brass Inc. Mr. Hinman, who will be located at the executive offices in New York, was formerly manager of aluminum sales for the Dallas division of Revere in Chicago.

Lothrop M. Forbush has been appointed engineer in charge of the vehicle development group, General Motors Engineer Staff, Warren, Mich. He joined the engineering staff in 1946 and in 1951 transferred to vehicle development where he later became assistant engineer in charge.

Otto L. Forchheimer has been appointed manager of the chemistry division of Trionics Corp., Madison, Wis. Before joining Trionics, Dr. Forchheimer was assistant director of research at General Abrasive Co. and Nilok Chemicals, Inc., Niagara Falls, N. Y.

Ray R. West, formerly head of the control devices section of Minneapolis - Honeywell Regulator Co., has been named manager of the company's newly created industrial controls division.

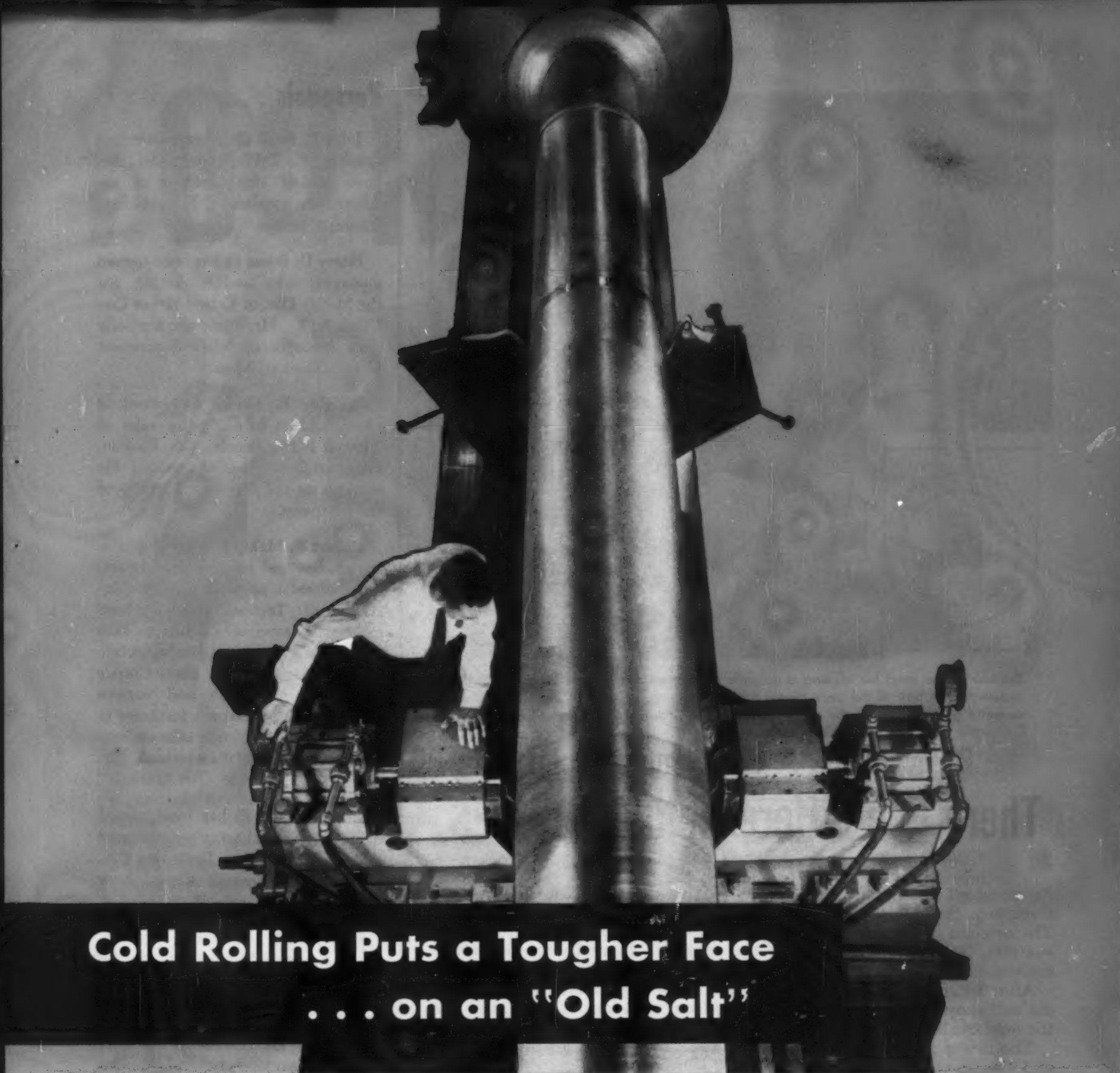
Frank J. Pryatel has been promoted from plant manager of the Outboard Motor Div. of the Oliver Corp. in Battle Creek, Mich., to director of overseas manufacturing operation. He will have his headquarters in the company's main office in Chicago.

Robert L. Sisson has been appointed general superintendent of the Canton and Gambrinus, Ohio, bearing factories of Timken Roller Bearing Co. Mr. Sisson has been with the company since 1937, and last held the position of superintendent of the Gambrinus bearing factory.

Maurice J. Day has been named to the newly created post of vice-president, commercial, for Crucible Steel Co. of America, in line with the expansion of its sales organization; he will have full responsibility for sales management at Crucible. Mr. Day joined the company in 1954 as director of research and development and in 1958 was named to the post of vice-president of technology.

Albert G. Haynes is now director of Keeney Research Div., Inc., Chicago, a subsidiary of J. H. Kenney & Co., Inc., where he directs manufacturing research and development and special work for government and industry.

J. G. Holmes and **S. L. Jackson** have been named assistant managers in the sales department of Union Carbide Metals Co., a division of Union Carbide Corp., New York. Mr. Holmes is assistant manager of the Pittsburgh region while Mr. Jackson is assistant manager of the eastern region, with headquarters in Phillipsburg, N. J.



To increase fatigue resistance, endurance limit and to fight the corrosive action of the sea, Erie Forge & Steel technicians cold roll ship's tail shafts as illustrated above. The life of the forged steel tail shaft is prolonged by cold rolling under the propeller and the after bearing. The surface toughness thus effected reduces fretting corrosion, minimizes pitting, costly failures and the hazard of propeller loss at sea.

Cold rolling is applied not only to new shafting but also for reconditioning existing ship's shafts, thus saving sizeable replacement costs in many instances.

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The Society of Naval Architects and Marine Engineers recommends that all ship's propeller shafts be cold rolled as a safety measure. This cold rolling process is approved by The Bureau of Ships, United States Navy.

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Personals . . .

John P. Brull, North American Smelting Co., Wilmington, Del., has been named vice-president of the Aluminum Smelterers Research Institute, Chicago.

Harry D. Stone has been named manager, sales and marketing, for the Metals Div. of Kelsey-Hayes Co., Utica, N. Y. Mr. Stone was formerly sales manager of NRC Equipment Corp., Newton, Mass.

Whitley B. Moore retired as vice-president in charge of sales of Timken Roller Bearing Co., Canton, Ohio, after 40 years of service. He remains on the board of directors of the company.

Robert F. Mehl, dean of graduate studies and head of the department of metallurgy at Carnegie Institute of Technology, has been granted a leave of absence to take a post as a consultant for scientific liaison between U. S. Steel Corp.'s research organization and various universities and research institutes in Europe. Dr. Mehl will take up residence in Zurich, Switzerland, the first of the year.

Ralph Mason has been named manager of metal scrap procurement and sales of the new Detinning Div. of Metal & Thermit Corp., New York.

Charles M. Hammond and **Stuart L. Ames** have been named senior research metallurgists at the research and development center of Allegheny Ludlum Steel Corp., Pittsburgh. Dr. Hammond will work in alloy development and applied research while Dr. Ames will be engaged in basic research on zirconium and other special metals.

John E. Cottier, Jr., district sales manager in Los Angeles for Jones and Laughlin Steel Corp.'s stainless and strip division, has assumed responsibility for all mill sales of the division. **John H. Sutton**, formerly in charge of carbon and alloy strip sales on the West Coast, is assistant sales manager in Los Angeles.

Lawrence P. Fricke has been named manager of the Milwaukee, Wis., district office of Revere Copper and Brass Inc.

Personals . . .

Don Hunter is now group leader in the nondestructive testing group of the quality division, Martin Co., Baltimore, Md.

Robert E. Lafferty has been transferred from the San Francisco Bay area as sales representative of Lindberg Engineering Co. to Downey, Calif., as service manager for 11 western states.

Peter F. Young, who formerly worked on materials development for the Titan and Polaris programs at the Sacramento plant of Aerojet-General, is now engaged in work on development of materials technology for liquid metal heat transfer systems and high-temperature uranium alloy fuel materials for specialized nuclear reactors at the Aerojet General California Nucleonics plant in San Ramon.

Howard F. Barton was recently elected vice-president in charge of sales and a director of the Stanley P. Rockwell Co.

John L. Scarry has joined A. M. Byers Co., Pittsburgh, as general superintendent of the Byers plant in Ambridge, Pa. He was formerly employed by U. S. Steel for 19 years, most recently as superintendent of steel producing at the Edgar Thomson Works.

A. D. Zar has been promoted to manager of the Detroit district sales office of the Babcock & Wilcox Co.'s tubular products division. His prior position was as the division's sales representative in the Milwaukee, Wis., district office.

Jack E. Morris, formerly director of product development for Jones & Laughlin Steel Corp., Pittsburgh, has been appointed general manager of the relocated container division of the company.

William W. Sieg, president, Titan Metal Mfg. Co., Bellefonte, Pa., a division of Cerro de Pasco Corp., was awarded the "Professional Manager Citation" by the Central Pennsylvania Chapter, Society for the Advancement of Management.

W. H. Bokum has been elected a partner of Cresap, McCormick and Paget, management consultants, in New York City.

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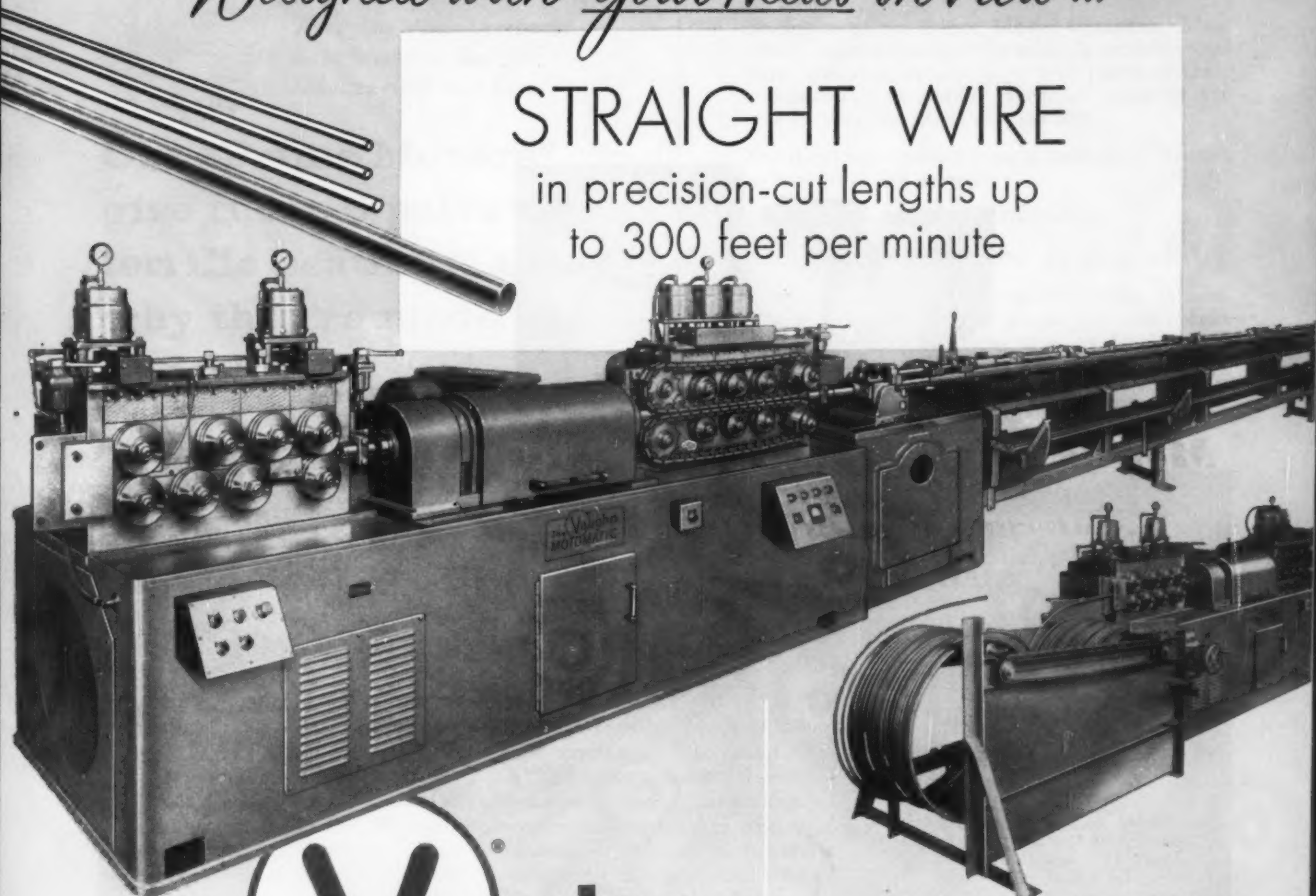
in precision-cut lengths up to 300 feet per minute



A quick-loading reel is designed to facilitate accurate starting of wire coils into chain feed . . . and to protect the operator from the revolving pay-off coil.

The Vaughn MOTOMATIC

Wire Straightening and Cutting Machine

Features **electric variable speed drive,** with full range speed control at operator's station . . . **adjustable center straightener arbor** that accommodates wide range of wire sizes . . . **caterpillar chain feed** which eliminates twist and processes entire coil, end-to-end . . . and an **accurately synchronized flying shear cut-off.** Keeps scrap to minimum . . . reduces labor, time and fatigue . . . and delivers uniform diameter and precision-cut lengths of straight wire. ● Full details in Bulletin 751—write for your copy. Consultation and quotations gladly provided on request.

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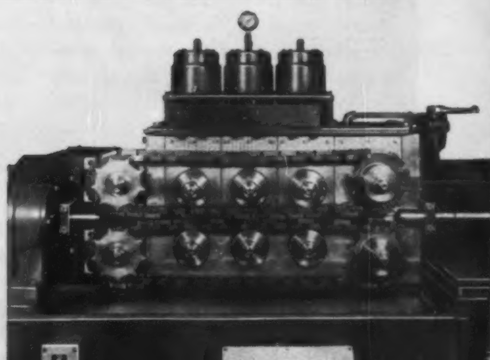


The caterpillar chain feed grips wire firmly without distortion, eliminating twist . . . and feeds the entire coil ends through the machine, saving wire scrap and operator time.

Metals Engineering **Digest**

. . . Interpretative Reports of World-Wide Developments

Metal Conference in Germany

Notes taken at the annual meeting of the Deutsche Gesellschaft für Metallkunde, Würzburg, Germany, May 29 to 31, 1959.

ALTHOUGH "Properties of Metals at Low Temperatures" was the main theme of the annual meeting of the Deutsche Gesellschaft für Metallkunde, the topics discussed encompassed many phases of physical metallurgy. After the formal opening by the president of the society, Dr. W. Deisinger, E. Justi presented a paper entitled "Properties of Metals and Alloys at Low Temperatures". In a systematic fashion, he discussed the theories underlying electrical and thermal conductivities of metals. Continuing with the factors underlying the galvano-magnetic effect, he rounded up a presentation intended as a theoretical and conceptual background to the ensuing talks.

The next speaker was W. Buckel who followed with "New Developments in Superconductivity". This phenomenon was discovered in 1911 by H. Onnes who observed that mercury lost its resistivity below 4.2° K.* By 1926 Onnes had found 23 superconductive elements with transition temperatures from 0.35° K. for hafnium up to 11.2° K. for technetium. Some compounds have even higher transition temperatures. For example, columbium hydride has a transition temperature over 20° K. He showed that the alkali and the alkaline earth metals (as well as gold, silver and copper) do not exhibit superconductivity, and that in resistivity the superconductive and normal states differ by a factor as much as 10.2. Other advances followed, and today about 180 superconductive alloys and compounds are known. In the future, there are possibilities for construction of galvanometers which can measure potentials as low as 10^{-12} v., and computer memory devices capable of switching velocities of 10^{-8} to 10^{-9} sec. through use of superconductivity.

The third speaker, R. Hilsch, reported on some interesting new thin film research. Through a special technique, it is now possible to deposit thin metal films on surfaces cooled with liquid helium. As one goes to lower and lower temperatures at which these thin layers are deposited, the residual resistivity of the metal increases while the X-ray diffraction lines broaden considerably. In bismuth between 2 and 14° K., very diffuse lines are observed. This may be due to particle size of about 20 Å or an amorphous liquid-like layer. Between 20 and 300° K., lines are extremely sharp. Gallium at 4° K. has an amorphous structure, at 15° K. a crystalline layer, between 20 and 55° K. a different crystal lattice, and between 85 and 273° K. the normal galium lattice is observed. This strange behavior is not restricted to metals exclusively; similar observations can be made on nonmetals. This technique is also suitable for studying alloy thin films since almost any metal can be alloyed by this method. In this fashion, one can produce amorphous structures in metals which are usually crystalline.

The second session was begun by a guest speaker from Holland, I. Druyvesteyn, who spoke on recovery after cold work, and discussed recent experiments dealing with cold worked and irradiated material. He showed that recovery is a stepwise process where the steps are temperature dependent and governed by the activation energies for motion of

*This stands for "° Kelvin". In this scale, 0° is absolute zero (−273° C. or −459° F.). To get the temperature in Kelvin degrees, add 273 to the temperature in Celcius (centigrade) degrees.

Metal Conference . . .

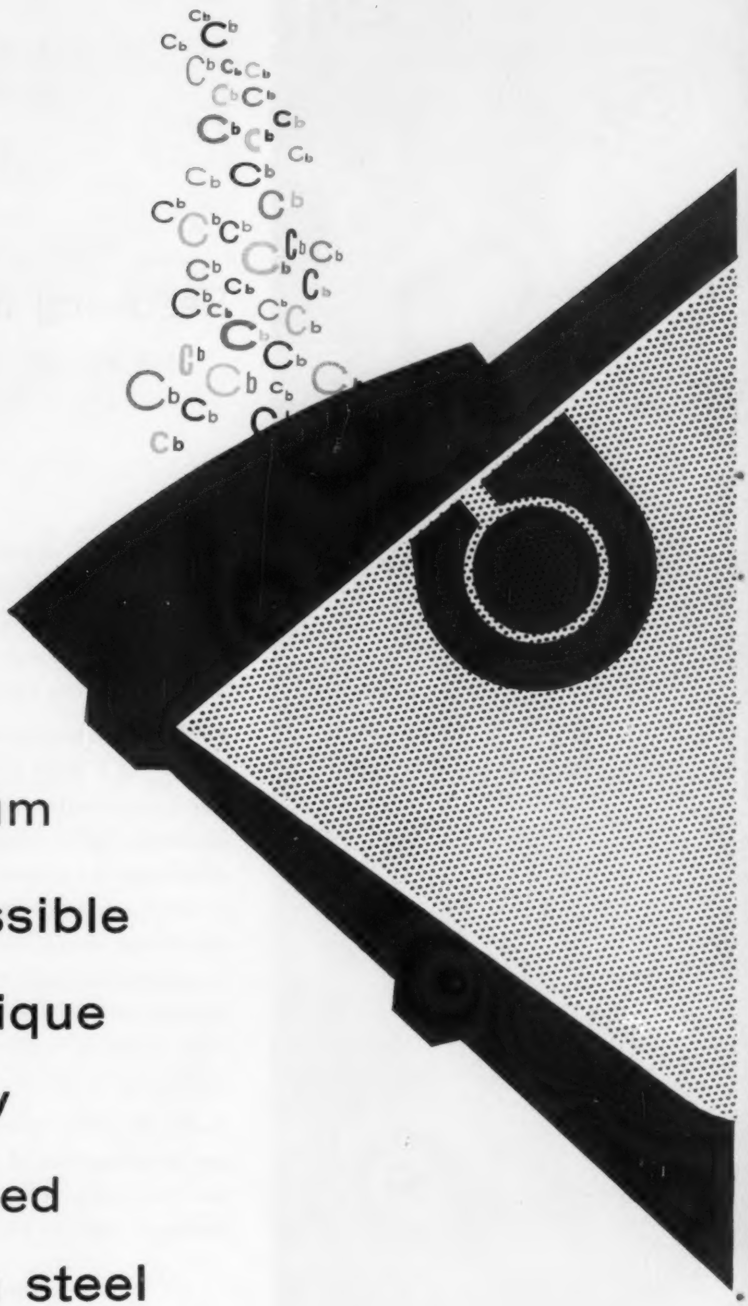
the imperfection. Fraenkel defects, lattice vacancies, dislocation, and finally recrystallization are responsible for the respective steps. Discussed also were the complicating effects that alloys introduce. Other properties such as thermo-electricity, internal friction, and stored energy are also affected during the recovery process.

Next, A. Kochendorfer dealt with the strength and changes of metal properties at low temperature. Starting with theory of elasticity considerations, he concentrated on low-temperature embrittlement of metals. Strength of metals and alloys, the meaning of single-crystal behavior, reasons for the occurence of brittle fracture and the extent of the embrittlement, aging, notch sensitivity, the role of flow processes, and the reliability of laboratory results for field application were all covered.

This discussion on low-temperature properties was ended by A. Barth whose paper showed some ways and means to provide materials which could meet the stringent needs of low-temperature technology.

The last two talks in this session were devoted to precipitation problems. H. Jagodzinski presented an interesting paper titled "On the X-ray Diffraction and Thermodynamics of Precipitation". Statistical methods (like the Monte Carlo method, for example) can be used to gain an insight into the problem of precipitation. He also pointed out that changes in the X-ray diffraction data in the vicinity of the critical temperature cannot unreservedly be interpreted as evidence for segregation of the precipitating phase.

The session concluded with V. Gerold's report on X-ray investigations of precipitation phenomena in supersaturated solid solutions. After discussing the ways in which parent lattice and changes in segregation species affect X-ray diffraction characteristics, he proceeded to show the species which will be precipitated in Al-Cu, Al-Mg-Cu, Al-Mg-Zn and Mg-Pb systems. Also, in the Al-Ag system the state of affairs is quite different because of extremely small lattice stresses which occur when the second phase precipitates. The growth kinetics of the precipitation phenomena in this system were also



Metal Conference . . .

studied in the 100 to 250° C. (212 to 480° F.) range.

The question of formation and disappearance of vacancies in metallic lattices occupied the attention of H. Wever. The author interpreted processes such as local deformation, building of crystallographic oriented surfaces and void formation in samples.

This talk was followed by an interesting presentation on "Slip Lines and Kink Bands in Copper Crystals", by S. Mader. An electron microscopic study demonstrated that copper crystals deform in three stages. In the first stage, fine slip lines (some as long as 100 microns with a step height of about 12 atom distances) are uniformly distributed. Secondly, there appears a textured structure with slip nonuniformly distributed. Step height is about 20 atom distances. Finally, slip lines bunch up into deformation bands with cross slip taking place within these bands. Frequency of cross slip increases deformation. All results were interpreted in terms of dislocation theory.

J. Geisler and W. Dahl discussed the influence of impurities on recovery and recrystallization of 99.999 copper. Nickel, aluminum, silicon, bismuth, silver and tin additions in concentrations from 0.01 and 0.1 as well as 3 to 5 at. % were investigated. Recovery and recrystallization progress was followed by X-ray diffraction and hardness measurements. These studies indicated that copper behaved unlike aluminum. To conclude the talk, an atempt to reconcile these differences was made.

Next, B. Liebmann discussed the influence of thermal treatment on the preferred orientation of commercial aluminum. He pointed out that there was no preferred orientation when iron was in solid solution in aluminum. However, when iron is segregated, preferred orientation is observed. These findings show reasons for past disagreements in the literature. Then, R. Reinbach spoke on the recrystallization of titanium, and the role of alloy additions in the process. They act to increase recrystallization temperature.

Phase Diagrams

The next two sessions were initiated with a paper by H. Diergar-

Metal Conference . . .

ten and G. Lucas on the behavior of eutectoid steel after annealing in the 200 to 300° C. (400 to 575° F.) range. The authors attempt to show that certain weak sites were developed in the steel; this accounted for scatter observed in the specimens tested.

Following this, L. Graf presented a new theory attempting to explain the stress-corrosion cracking of alpha brass. He seems to combine his recently advanced alloy effect with electrochemical considerations.

He was followed by M. Otter on the oxidation of spherical nickel crystals. The crystallography of the process and the observed equiaxial relationships were clearly presented.

The results of a motion-picture study of electron diffraction (applied by W. Prinz) on the Ag-I and Ag-Cd systems were next shown. As a novel approach to phase diagram studies, this technique employs thin layers of the desired alloys. Heat treatments are conducted in the electron diffraction apparatus while data from the specimen are simultaneously recorded.

This was followed by H. J. Schüller and P. Schwaab who discussed thin films of Cr-Fe (30, 45 and 60% Cr) and Cr-Ni (55, 75 and 85% Cr). The authors were able to prove that the sigma phase existed down to 300° C. (575° F.) in the first system, and in the 400 to 700° C. (750 to 1300° F.) range in the second.

The next paper was "Constitution and Properties of Zr-Pd Alloys", by K. Anderko and H. W. Schleicher. For pressurized water vapor attack, alloys containing from 0.2 to 3.0% Pd showed best behavior.

The last session, on property measurements, included five speakers. To begin it, G. Reinacher reported on short time testing of platinum and platinum-iridium alloys. Data were obtained with a specially devised hot stage microscope in which the specimen could be observed microscopically up to 1200 to 1300° C. (2200 to 2375° F.) while under load.

The last speaker of the meeting was F. Förster who gave two papers. In the first, he discussed electronic methods for measuring elastic moduli with great sensitivity; these, according to him, are useful for study-

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Metal Conference . . .

ing various physical metallurgy processes associated with modulus changes. In this second paper, he reported on instruments which could measure permeability with great accuracy. Commercial equipment enables the detection of ferrite in very small amounts.

The reporter wishes to emphasize that one can but skim over the contents of most papers in the space allowed. It is, however, hoped that these brief references will be enough to interest readers working in similar fields to get in touch with the parties* concerned for more detailed and worthwhile information.

R. Bakish

Electropolishing

Digest of "The Mechanism of Polishing", by K. F. Lorking, *Journal*, Australian Institute of Metals, May 1959, p. 22-26.

To be mirrorlike, a metal surface must have both microsmoothness and macrosmoothness. Microirregularities scatter incident visible light at a small angle so that a surface appears dull. A microsmooth, but macrorough surface, is brilliant to the eye, because all the incident light is reflected at a large angle to the surface. The sharpness of image definition is determined by the degree of macrosmoothness.

Electropolishing readily microsmoothens a surface. However, the degree of macroroughness determines whether a practical amount of electropolishing can convert a macrorough surface to a macrosmooth surface.

The author proposes different mechanisms for micro-electropolishing and macro-electropolishing. For either action to take place, high spots must dissolve preferentially. In both actions, cation formation (transfer of metallic atoms from metal lattice to become ions in solution) must be controlled. The macro-electropolishing required takes place on too large

***Editor's Note: Dr. Bakish also sent a directory which includes the names and addresses of all speakers. Since space is limited in the digest section, these were not included. However, *Metal Progress* will gladly furnish any of these listed addresses if desired.**

Electropolishing . . .

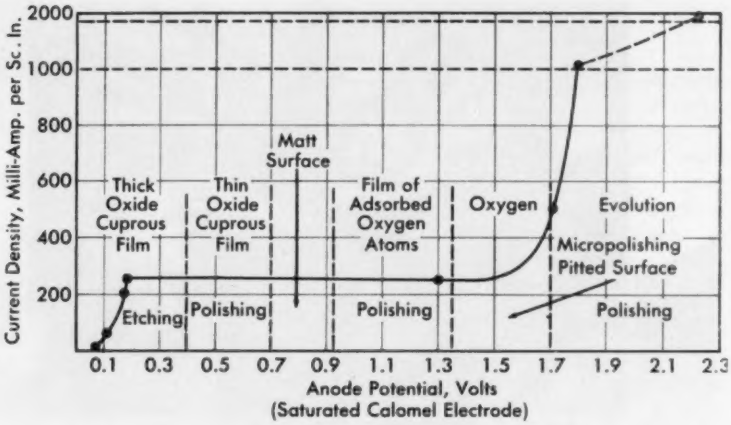


Fig. 1 – Anode Potential-Current Density Relationships on Horizontal Copper Anode. Note that polishing occurs in the region of gas evolution, as well as in the nongassing region

a scale for control by reactions right at the electrode surface. Diffusion of cations away from the surface is proposed as the process limiting the current and thus limiting the formation of cations or rate of metal dissolution.

Macrosmoothing results when the electrolyte provides a viscous liquid film at the anode surface such that the concentration of cations is high in the film. The film is thinner at projections on the surface, resulting in more rapid diffusion of cations at these points; metal dissolution is more rapid from projections than from recesses, and thus macrosmoothing results from the preferential solution of the high spots.

Lorking proposes this mechanism on the basis of data for electropolishing copper in phosphoric acid solution. Phosphoric acid is relatively viscous and becomes more so as dissolved copper concentration increases. This condition increases the smoothing efficiency, because the limiting current density decreases over the concave areas of the surface where the copper-rich solution tends to accumulate.

The limiting current density is given by:

$$I_{lim} = kZc_s/\delta \cdot \eta \ (c_s, c_o)$$

where c_s is the limiting concentration of the cation at the anode surface, c_o the cation concentration in the bulk of the electropolishing bath, δ the thickness of the anode film, η the viscosity of the anode film, and Z and k constants.

This equation shows that as dissolved metal increases toward c_s, its maximum concentration, the current density decreases and metal removal decreases. On the high spots of the surface, diffusion through the thinner film is more rapid, and concentration of dissolved metal (cations) is farther from c_s. More current can flow at the high spots, metal removal is greater and smoothing results.

Ultimately, the high spots are lowered to a point where film thickness over them is negligibly different from that over the concave areas. Then, diffusion of cations (dissolved metal) away from the surface is so nearly the same at all areas that the current density is the same at all areas. Microhigh spots cannot be selectively dissolved, because of differences in cation concentration gradient. Therefore, micropolishing involves a different mechanism for preferential solution of microhigh spots because of differences in diffusion rates of cations from the anode surface.

Lorking proposes that microsmoothing results from variation in the density of packing of polar molecule chains oriented by and held to the anode surface by its electrical charge. This film thickness is the same order as the height of microirregularities. The polar chains are

Electropolishing . . .

packed closely in microconcaves and more loosely on microprojections (micropeaks).

For micropolishing to occur, the polar film must be relatively rigid or viscous enough so that solvated metal can diffuse away more rapidly at the film micropeaks. Such behavior can be expected for electropolishing copper in phosphoric acid solutions, because an electrolytic film of saltlike structure is formed. Such a film also explains the absence of etching in an electropolishing solution. Random dissolution of metal atoms takes place by transfer into vacant sites in the saltlike film, and the high potential gradient across the film causes solution to take place immediately upon occurrence of a vacant site, irrespective of crystal face or phase composition. When the film grows thicker than the electric field of the anode, it breaks down enough to allow complete solution of the metal in the bulk of the electropolishing bath.

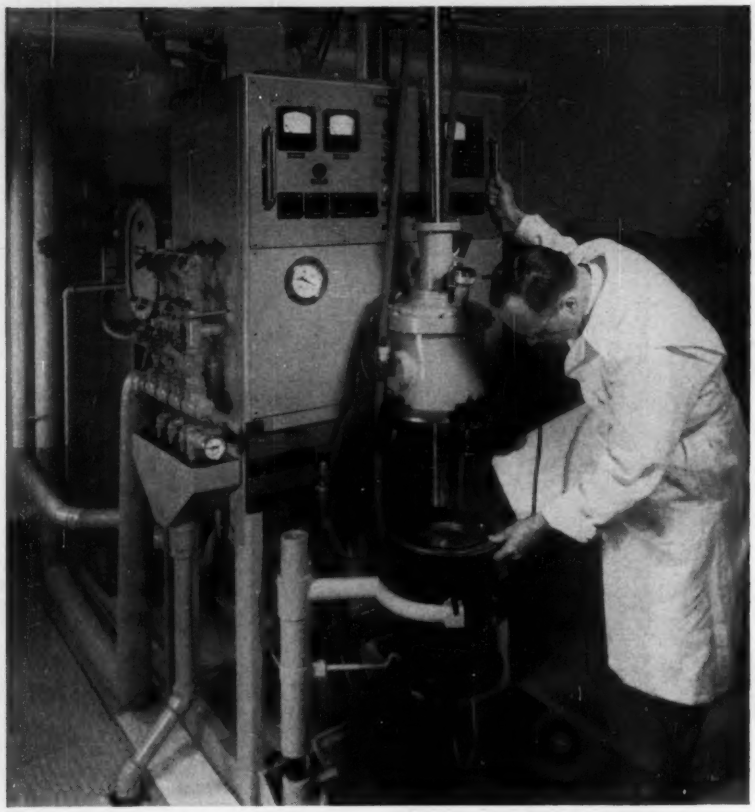
The discussion is based entirely on electropolishing copper in phosphoric acid solution with current density-voltage relationships as illustrated by Fig. 1. Of interest would be an article explaining the role of the gas film on the mechanism of electropolishing. C. L. FAUST

Aluminum Alloys . . .

(Continued from p. 91)

Al-Cu Alloys, because of the high solubility of copper in aluminum, offer an attractive possible combination of strength and specular reflectivity in the bright anodized condition. Their potentialities for extruded applications are also worthy of investigation. Recent work makes it apparent that the most beneficial effect to be derived from copper is as a third or fourth component of ternary or quaternary systems — for example, Al-Mg-Cu or Al-Zn-Mg-Cu.

Al-Zn-Mg alloy systems have produced well-known, very strong sheet and extrusions. They have the ability to age harden and give mechanical properties considerably better than any of the other alloys mentioned above. Furthermore, both magnesium and zinc in the alumi-



Aluminum Alloys . . .

num matrix are highly soluble and the color and refractive index of their oxides are comparable with the same properties of the anodic film. These factors indicate that Al-Zn-Mg alloys should bright anodize satisfactorily in both sheet and extruded form. Further additions of copper should provide better brightening characteristics as well as improve the mechanical properties.

Many of the bright anodizing troubles can be traced back to the metal manufacturing processes. Reticulation in sheet, mentioned earlier, was studied by Herenguel in France. He attributed it to lack of control of grain size during casting. Additions for refining grain size in the ingot must be used with caution in casting superpurity materials; the casting conditions must be very carefully chosen. Pre-extrusion of the sheet ingot, although efficient in breaking down large grains, limits the width of the sheet that can be produced.

In rolling operations, a heavy reduction of slab thickness is essential and this is difficult for the thicker gages. Cladding with material in which the structure has been broken down by previous hot rolling, or cladding with pre-extruded strip, may solve this problem.

Careful scalping of the ingot is necessary to remove surface segregation, oxide inclusions and laps. Considerable work has been done recently to determine the optimum depth of scalping. Pickling of the hot mill strip, prior to cold finish rolling, is desirable. Some ingenious devices have been installed in some mills to pickle continuously.

Adequate soaking of the ingot is especially important. If pre-extruded stock is used, soaking can follow normal techniques, but if the cast ingot is to be broken down directly, the structure must be thoroughly homogeneous. Choice of temperature and cooling rate are important, since addition elements should be kept in solution.

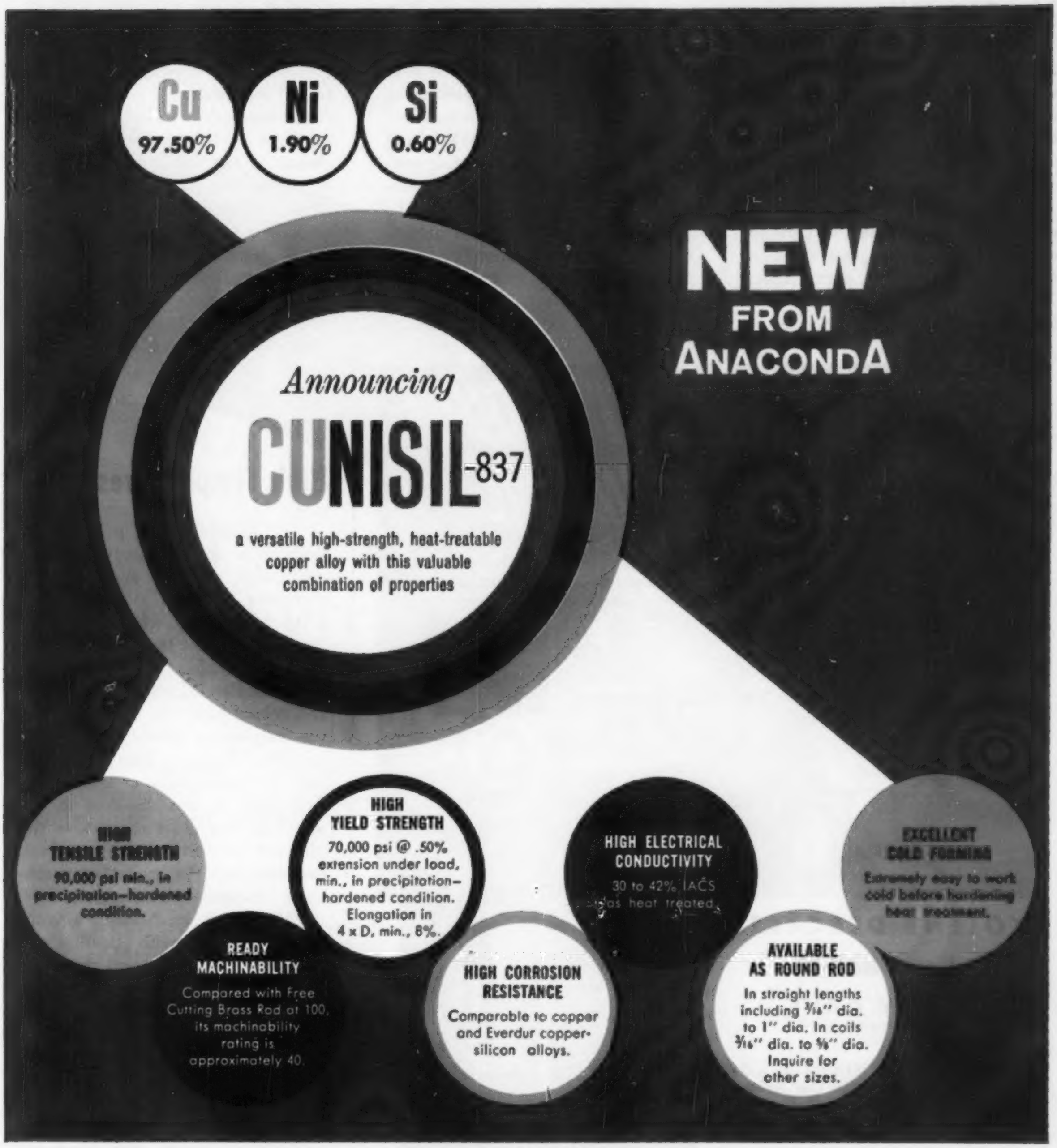
In the hot mill, adequate lubrication is essential and maintenance of the rolls is a critical matter. Cold rolling presents few aspects detrimental to bright anodizing of material, although the rolls must receive the same careful attention as

Aluminum Alloys . . .

in the breakdown operation. Lubricants must be chosen which do not stain the product. Precautions should also be taken to avoid airborne grit and dirt; canopies may be erected over the rolls and great care must be exercised in handling, packing and storing the sheet.

Work hardened material usually requires a recrystallization anneal (although it may be temper annealed to a required degree of hardness). Published information on this subject relates primarily to alloys based on superpurity aluminum with 3% and 5% magnesium. Minimum cold reduction should apparently be more than 25%, so as to avoid grain growth, and less than 75%. The minimum annealing temperatures are given as 615° F. (325° C.) for the 3% alloy and 520° F. (270° C.) for the 5% alloy. If these limits are not observed, the magnesium atoms tend to segregate along the grain boundaries of the as-rolled material rather than on the boundaries of the recrystallized grains, and thus give a mottled streakiness on anodizing. With alloys containing 1.5 to 2.0% magnesium, a recrystallization temperature of about 660° F. (350° C.) seems desirable. Obviously the degree of cold work and the recrystallization time and temperature have to be adjusted mutually so as to produce a reasonably fine-grained material. Suitable manipulation of established techniques may suffice – as, for instance, partial annealing instead of recrystallization.

It is not so difficult to produce extrusions with surfaces suitable for bright anodizing. Recrystallization is not likely to cause acute problems because it is usually possible to quench at the die and so avoid a formal solution treatment with attendant recrystallization. However, the same careful control of casting conditions is desirable and the ingots may need to be scalped prior to preheating. Discard should be adequate to avoid any back-end defects. The standard of finish on the dies and mandrels must be very high to prevent die scoring. Indeed, all handling, extrusion and drawing techniques need to be examined with care in the light of the very high requirements on surface quality. For example, die cleaning with caustic



METALLURGICAL COMMENT. Most of the nickel and silicon in heat-treated Cunisil are present as an intermetallic compound, nickel silicide, and it is the precipitation of nickel silicide in the form of particles of submicroscopic size by a relatively low temperature heat treatment that accounts largely for the distinctive properties of the alloy.

Prior to the hardening heat treatment, the alloy is brought to a proper condition for hardening by giving it a solution anneal at a much higher temperature and then a quenching from this temperature; at this stage the alloy is quite soft and in a condition for drastic cold-working operations. The hardening heat treatment consists of heating at a controlled temperature for a definite length of time to obtain the desired mechanical properties.

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Aluminum Alloys . . .

is not recommended; and the conventional lubricants and lubrication techniques may also stain the metal surfaces.

Extrusions in the magnesium silicide alloys have been most generally accepted for bright anodized applications because of their very desirable combination of good mechanical properties, ready extrudability and satisfactory response to both brightening and anodizing. Higher extrusion temperatures are recommended so that Mg_2Si may be kept in solid solution. Higher preheating temperatures are desirable to effect uniform dispersion of the Mg_2Si, and fast cooling from the preheating temperature will avoid its reprecipitation. Also, rapid cooling from the extrusion temperature will avoid undesirable recrystallization and precipitation of Mg_2Si. If artificial aging is needed, overaging must be carefully avoided, because an excessive amount of Mg_2Si or massive growth of the crystals will cause a loss of reflectivity.

Commercially acceptable bright anodized finishes can only be produced on aluminum if the metal is of the proper metallurgical composition and structure. The principles underlying the design of suitable alloys have been outlined. The aluminum alloys now available have been listed and the direction of present research has been indicated. The effects of manufacturing processes and their control have also been outlined.

High Temperatures . . .

(Continued from p. 95)

research in atomic energy, physical metallurgy, ceramics and inorganic chemistry.

As for the Norwegians, at the "Sentralinstituttet for Industriel Forskning" in Oslo, there is work on the oxidation kinetics of titanium and columbium. So far, the oxidation mechanism seems to be quite complex. Not only does the oxygen react to form a more or less protective layer, it also dissolves in the metal causing great changes in the physical properties of the metal. Furthermore, the oxidation mechanism changes with temperature.

Other work in Norway is concerned largely with studies in ceramics. For example, there are investigations on the corrosion of refractories in melts, the equilibrium between solid oxides and atmospheres which contain oxygen, solid solutions of various metallic sulphate compounds, and kinetics of mullite formation in some kaolins.

High-temperature research is not limited to the Western European countries alone. Also speaking at the symposium was Hisao Mii who represented Japan. As head of the Mechanical Engineering Div., Government Industrial Research Institute, at Nagoya, he was well acquainted with Japanese progress in the high-temperature field. A long section of his paper was devoted to a new solar furnace erected recently at the Government Industrial Research Institute.

Interest in constructing such a

High Temperatures . . .

furnace developed when it became necessary to test high-temperature refractories. The prototype model, built of aluminum plate, was constructed in August 1955. Just after it was completed, its performance was tested by melting several metal oxides. While colored oxides such as Cr_2O_3 (melting point, 4125° F.) melted readily, white specimens (SiO_2 with a melting point of 3100° F.) were difficult to melt because of their greater reflectivity. However, such oxides would melt with little effort if coloring matter was added.

Though the first solar furnace performed as expected, there were a few drawbacks. Its radiation density was 1940 watts per sq.in. at most; this value was considered too low. Two causes were suspected: The mirror was not true parabolically because it was built up of many small mirrors with circular arcs, and buffing (to improve reflectivity) distorted the soft surface.

Since the technique appeared very promising, however, a second furnace was projected. Before its construction, several design problems had to be faced. One question was, "What type was most suitable?" Although the type in which a reflecting mirror faces the sun directly (such as the first solar furnace) has a great advantage of having only one reflection, the focus is located above the reflector. Accessibility to the specimen is not good, and molten material may fall and spoil the mirror surface. A heliostat-type solar furnace, in which the radiation is reflected to the parabolic mirror by a plain mirror, had additional reflection loss because of the heliostat. However, it has good accessibility to the specimen, and there is less likelihood of damaging the mirror surface because its optical axis is set horizontally. Due to these advantages, the latter type was used for the new solar furnace.

There were enormous difficulties and expenses in constructing a new paraboloid which satisfied all requirements. Because of this, attention was paid to a searchlight mirror of military surplus, which was completed for the Japanese Army during World War II. Values of aperature, focal length, and aperture ratio of the most common searchlight mirror are satisfactory. The reflectivity is


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High Temperatures . . .

0.75, and the geometric accuracy is so good that the scattering of the focus may be less than ½ in. The searchlight mirror actually obtained for the second solar furnace was unexpectedly good in its geometrical accuracy and is giving excellent service. A preliminary test for checking its performance showed that the surface of an irradiated ThO_2 (melting point, over 5400° F.) sample was melted instantly.

Work on solar furnaces is not the only research that occupies the Japanese. Other interesting projects include the melting of carbon. This may sound odd since it is well known that carbon sublimes (passes off as a gas) at ordinary pressures. However, if the pressure is high enough, carbon will melt when the proper temperature is reached.

The triple point of carbon has been thought to be 100 atm. and 6700° F. Experimental apparatus (shown in Fig. 2 on p. 95) was constructed from an autoclave with electrodes attached for heating.

The specimen was a thin graphite rod, the middle portion of which was reduced in diameter for easy melting. The vessel was evacuated, and argon added up to about 100 atm. Argon pressure was increased gradually as the specimen was heated by electric current supplied from an induction voltage regulator. The condition for melting a specimen (about ⅛ in. in diameter at the middle and 1 in. long) was 21 to 23 volts and 350 to 400 amp. under 150 to 160 atm. of argon.

As is apparent, high-temperature research in other countries is flashing off in all directions. Throughout the world, coming years will bring to fruition the many projects that occupy research workers today.

Hot Pressing Powders...

(Continued from p. 108)

and a perforated steel end plate welded on. The canisters were now heated for extrusion (generally at about 1900° F., but always well below the temperature of the beryllium-iron eutectic – 2130° F.). Air was expelled through the graphite

Hot Pressing Powders...

disk which acted as a filter to prevent ejection of any beryllium powder into the furnace atmosphere. After allowing time for the powder mass to be uniformly heated, the canisters were removed from the furnace and extruded by a conventional press.

Copper plating the outside of the canister reduced the extrusion pressure by about 25%, but there was some contamination of the extrusion dies with copper. However, copper-plated billets formed straighter extrusions. Rods and tubes were straightened while still hot from the extrusion press, and the steel sheaths were removed when cold by pickling in 25% aqueous nitric acid. In some instances, a groove was cut along the rod or tube, and the steel sheath was peeled away. Surface contamination was removed by pickling in hydrofluoric acid mixtures, or by further machining.

Extruded beryllium, in its original steel sheath, was forged and stamped to various shapes*. After sections were cut from the extruded beryllium rods (without removing the steel sheath), steel end plates were welded on. The completely sheathed beryllium was now heated to about 1000° C. (1850° F.) and forged or stamped with standard hammers and dies. Then, the sheath was removed in dilute nitric acid. Reactive powders of metals such as beryllium and zirconium were forged in sheaths. First they were precompacted at 8000 psi. in mild steel canisters (height and diameter about equal) with a small quantity of volatile hydrocarbon added to expel air during heating. The filled canisters, fitted with internal filter disks and perforated end plates, were heated slowly to the desired temperature (1900 to 1975° F. for beryllium, and 1750° F. for zirconium sponge), transferred quickly to the forging hammer, and flattened to about one third of the original height. The steel sheath was subsequently cut away or dissolved off by dilute nitric acid.

When chlorine content was low (about 0.06%), beryllium flake produced sound metal when consoli-

(*Continued on page* 190)

*This work was kindly undertaken by High Duty Alloys Ltd., Redditch, England, and thanks are due to E. T. Stewart-Jones for his assistance.

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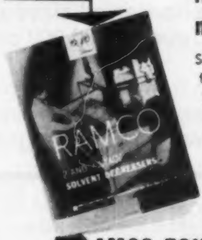

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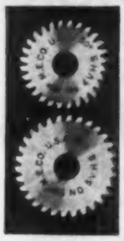

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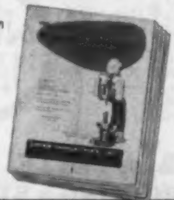

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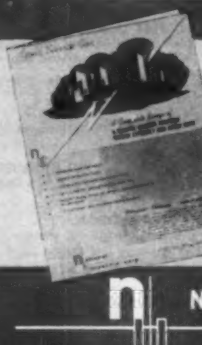

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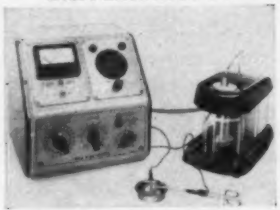

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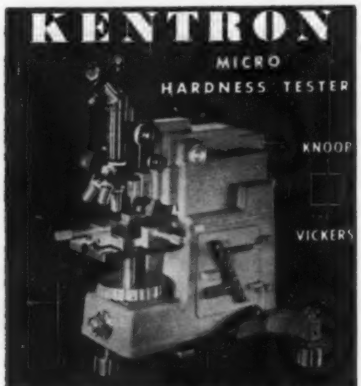

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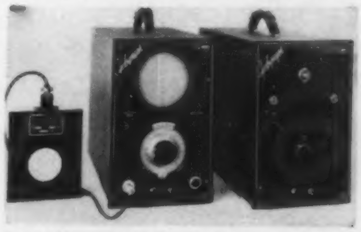

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dated in this way. However, flake with higher chlorine (about 0.1%) gave unsatisfactory results, the metal suffering localized corrosion apparently from entrapped chlorides. The consolidated zirconium sponge generally contained undesirable inclusions, probably derived from traces of magnesium chloride remaining after vacuum heat treatment in the manufacture of the sponge.

Fabricating Specific Parts

A few examples of materials and components fabricated by the methods already outlined will be described briefly. Beryllium powder was hot compacted at 820° C. (1500° F.) with a pressure of 27,000 psi. to produce disks, rings, and cylinders from which various components were machined. A selection is shown in Fig. 3, p. 107; at bottom are ferrous alloy slabs with elliptical cooling channels. These are prepared by cold compacting a powder mass containing wax rods set in a plane perpendicular to the axis of compaction. Dewaxing and sintering followed. Above this (left) is a beryllium pressure tube for containing gases at pressures up to 3000 atmospheres (for X-ray work) prepared from hot compacted beryllium powder. At right is a rectangular beryllium cyclotron target, compacted in a mild steel frame at 800° C. (1475° F.) and machined. In the middle is a beryllium X-ray window, 0.01 in. thick, compacted in a Nimonic 75 frame at 850° C. (1560° F.).

At the top of Fig. 3 are straight and curved strips of 'boral' plate. This plate consists of a layer of boron carbide and aluminum cermet put between aluminum sheets; it is used as a neutron shielding material. In fabricating this material, the cermet layer was formed by both cold and hot compacting in the same aluminum frame. A large frame, 32 × 13½ × 3 in. was welded from an extruded aluminum section (3 × 1 in.). This was placed on the bottom flat die of a press which was filled with a tamped mixture of −240 mesh boron carbide and −72+200 mesh aluminum (atomized) powder in proportions of 30 to 70 by weight. The whole setup was cold pressed to 1.6 in. between

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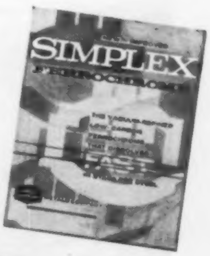

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Hot Pressing Powders...

clean flat dies under 12,000 tons. The resulting framed compact, which was quite robust for handling, was superficially cleaned by brushing and air blasting to remove the boron carbide fins from the surface of the compact, where they would interfere with bonding to the cladding plates. The compact was now clad with 0.4-in. aluminum plates on each side, and the plates were welded to the frame. This enclosed the compact material, but left a few small gaps for gases to escape during rolling. The slab was heated to 620° C. (1150° F.) in an electrically heated billet furnace and rolled in nine passes to 0.25 in. thick in the direction of the smaller dimension of the frame, the gas escape holes being kept to the rear. The rolling temperature was kept above 280° C. (540° F.), but reheating was not generally required. After trimming of the rolled aluminum frame, the boral plate was about 8 ft. 6 in. long and 2 ft. 6 in. wide. Samples tested in a current of thermal neutrons had an average attenuation factor of 1300, and a minimum factor of 1000.

Figure 4, p. 108, shows forgings, stampings, and other parts of steel-sheathed beryllium. At the bottom are two types of stampings. They are shown before and after the steel sheath has been dissolved away by dilute nitric acid to illustrate the good matching of the contours of the beryllium and the steel outer surface. Above these are samples of forgings with half the steel sheath removed from each. The blank forged with a waist is satisfactory, but the extruded rod flattened axially shows undesirable edge cracking. Next to these (right) is shown a test specimen which has been machined from extruded beryllium.

Sponge Iron . . .

(Continued from p. 115)

Fierro Esponja S.A. is installing a new 500-ton-per-day plant next to the existing unit. This new plant, scheduled to be in operation early in 1960, has been designed and is being built by the M. W. Kellogg Co.

Raw material requirements per metric ton (1.1 short tons) of iron, in the sponge iron for an 85% re-

Sponge Iron . . .

duced ore, will be lower than for the existing unit. The following values are expected: Natural gas, 18,000 cu.ft.; electric energy, 7 kw-hr.; water, 141 cu.ft.; ore, 1.75 tons. Labor will drop to about one-half man-hour since the whole operation will be simpler. Fuel economy will be achieved because of better heat conservation. Less electric energy will be used because steam is employed as prime mover in turbines. (Hence, very little excess steam is left to be used elsewhere.) Since each turbo-machine will have its own electric motor standing by, there is considerable versatility in plant operation. Electric power can be used whenever economic conditions make it worth-while to allot steam to other uses.

Economic success of Fierro Esponja's sponge iron plant, coupled with an increase in the quality of rolled products fabricated with this sponge iron, has made this departure from conventional ironmaking processes very attractive. This new gaseous reduction process will undoubtedly have an important bearing on future developments of the world's steel industry.

Training Metallurgists . . .

(Continued from page 127)

state. Limited and casual encounters with them prompt the observation that they have unlimited capabilities of shunning the cult of sparkling personality. Clothes are dull and faces show grave preoccupation with routine studies. Even among the galaxies of girl students to be found in every establishment, there was but little outward sign of feminine freedom, frivolity, or individuality which bless their sisters of the Western world.

As previously mentioned, timetables are heavy and patterns of behavior are well disciplined. Two organizations play an important part in the management of student life. One, the "Students' Trade Union", is primarily concerned with welfare, including cultural activities, social insurance, supply of meals, living conditions, and in fact very many of the responsibilities and administrative arrangements which, in this

Training Metallurgists . . .

country, are seen to by the school authorities. The other organization is the "Komsomal" which takes care of certain educational functions such as the organization of small groups of students, normally from the same year in the same department, who endeavor to do everything together in the search for culture at the opera, theater, art gallery, exhibition, discussion group or country ramble. The objective is clear – in brief, the student "strengthens the collective" by conformity to the precise plans made for him.

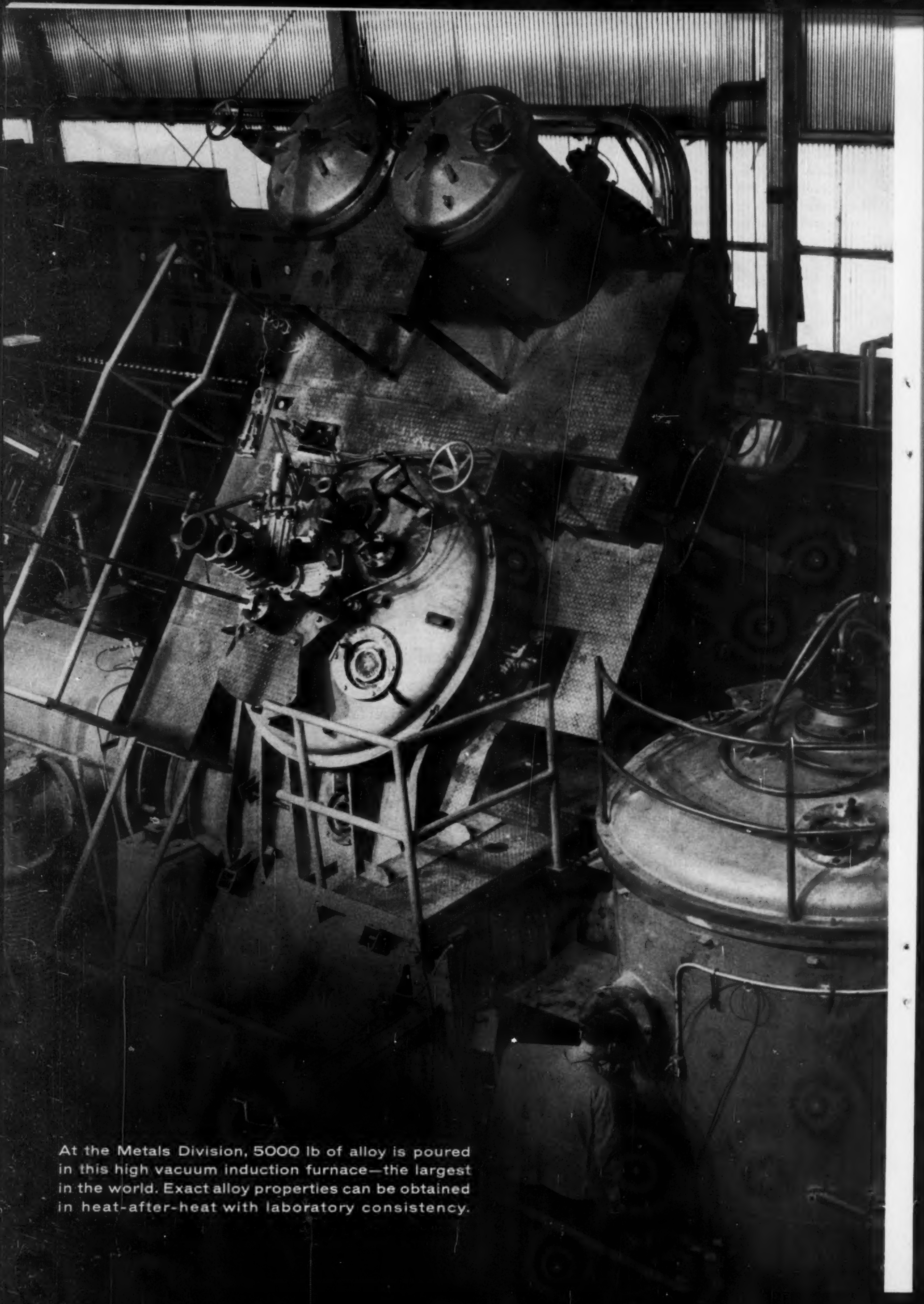
Many students come from distant parts and even from overseas. It was indeed quite a shock to hear a lecture at Moscow University in the English language and then to note that the students were a group of Egyptians! At this University there are hostels, accommodating 6000 students with single or double rooms rather sparsely furnished and of limited size. At other institutes the accommodations are even more austere; four to six students may be packed into a bedroom, sitting-room, study with real economy of space. The students in such a room are usually of the same year and the same department and form a "collective group" where individual differences can be ironed out and where mutual assistance can be provided to each other's academic progress and uniformity of outlook.

Rewards

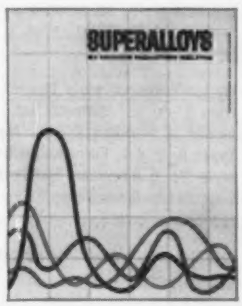
Students receive grants ranging from about 300 rubles per month in their first year to about 500 in their final year. Hostel accommodation may cost 15 rubles per month and meals may swallow up most of the balance for the first-year student, unless, of course, he cooks his main meal himself. Postgraduate workers may receive about 1000 rubles per month, while the senior teaching staff will get up to 10,000 rubles per month and perhaps even more. By comparison, the average wage in a Moscow car factory is about 900 rubles per month. Cost of living is difficult to compute; while the basic necessities of life are reasonably cheap, the luxuries can soar to astronomical levels.

We were told that graduates are readily absorbed into industry, teaching staffs, research institutes, or elsewhere and, in fact, generally fit into the planned system whereby supply equals demand. In visiting several industrial establishments, we were struck by the very large numbers of graduates employed – far greater ratios than those found in England or in the United States. The reasons were not made clear to us, but it is certain that many of them are employed in tasks which we assign to technicians, draftsmen and other skilled workers.* It is to be remembered that Russia has ex-

*EDITOR'S FOOTNOTE—An interesting "self-criticism" of one branch of engineering education in the U.S.S.R. is found in the Foreword to the January 1959 issue of their journal *Automatic Welding,* as translated by the British Welding Research Association. This unsigned article emphasizes the large expansion of welding techniques necessary if the equipment is to be built to meet the new seven-year plan for expanding heavy industry by about 60%. To meet this challenge, "serious attention must be paid to improving the training of fresh teams, familiar with



At the Metals Division, 5000 lb of alloy is poured in this high vacuum induction furnace—the largest in the world. Exact alloy properties can be obtained in heat-after-heat with laboratory consistency.


SUPERALLOYS

Training Metallurgists . . .

panded her economy at an enormous pace and the "traditional" workers with their locally developed skills are few and far between. Thus the ready availability of trained technologists may be a godsend in providing a man for the job, almost ready-made. Furthermore, pioneering is the spirit of the times in Russia, where new industries spring up in more and more remote places. Here again the trained technologist will have the versatility and aptitude for the task.

The foregoing will, I hope, give the reader a modest idea of the task which Russia has set herself in modern technological education and how she is achieving really vital objectives. Numbers alone can strike a formidable note, and let us have no doubts as to the average caliber of the product. Science and technology attract the pick of youth, all anxious to develop and prosper in that country; mental discipline is severe and the ultimate objectives are clearly set by the unlimited authority of the state.

The high degree of specialization which is possible is particularly noteworthy and Russian industry is bound to profit thereby. In this education, there are the closest ties between teaching, research and industry and in this factor alone we have much to learn from the Russians.

Pig Iron From Iron Sulphide

Digest of "The Iron and Steel Industry of Western Canada, With Particular Reference to British Columbia", by G. P. Contractor, Ferrous Metals Section, Canadian Department of Mines, Ottawa, Ont.

THIS 100-PAGE REPORT really supplements the somewhat larger one issued in 1954 on the same subject and briefly reviewed in *Metal Progress* for June 1955 (p. 108). In order to show what the situation is in the western province, the author reviews the whole Canadian industry, and outlines some unconventional processes as well. From the standpoint of economics, the prospects of a large industry in British Columbia ore are only about 10,000,000 tons, and this would certainly not support a blast furnace operation using 1,000,000 tons per year. In addition, there is very little demand for pig iron in British Columbia, and, also, practically no source of coal which would make a satisfactory coke.

The amount of steel consumed in British Columbia in 1956 was only

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welding techniques", in the words of the Russian author. He continues further:

"At the overwhelming majority of universities in our country, welding engineers are trained at the mechanical faculties, where future specialists are taught about machine parts, theoretical mechanics, the theory of machines, technical draftsmanship, descriptive geometry, and so on, but they are not taught sufficient about the science of metals. On leaving an Institute, a graduate receives the title of Welding Engineer-Mechanic, but actually he is more a mechanic than a welding engineer.

"To meet the new conditions, a welding engineer must have a profound knowledge of metallography and metal physics, including the heat treatment of metals, the metallurgy of various steels and alloys, physics, chemistry and physical chemistry. However, the necessary attention is not being paid to these subjects at the mechanical faculties. It has now become necessary to pay *considerably more attention to the study of the metallurgical process.* Only on this condition will our industry receive teams of engineers capable of improving Soviet welding techniques."

400,000 tons, and about 40% of this was produced locally in small plants melting steel scrap in electric furnaces. About 230,000 tons of steel are imported into the province and this cetrainly wouldn't support an integrated steel plant which must make at least 1,000,000 tons a year to make an economical investment. Moreover, the product mix is very unfavorable: 90,000 tons of structural shapes, 80,000 tons of bars, and about 58,000 tons of hot rolled strip.

The author states that steel scrap sells in British Columbia at $28 to $30 a ton. This can be melted in electric furnaces at a very attractive figure, much less than in an open-hearth furnace. The necessary additions of electric furnace plants could be made if the necessary rolling mills could be justified.

A very interesting section of the report deals with 35,000,000 tons of iron sulphide tailings which have been accumulated by Consolidated Mining and Smelting Co. — a stockpile that is growing at the rate of 900 tons a day. These tailings can be sintered in to an ore of 58% iron, 10.7% silica, 0.01% sulphur. Traces of lead, zinc, tin and copper remain but experimental pig iron has been made with very low amounts of these impurities. Since coal mines are also close by and electric power at 2½ to 3½ mils is available, this should make a very attractive location for an electric pig iron furnace.

Since these tailings have no other value than cost of sintering, the price of iron ore charged to the furnace would be low. Mr. Contractor thinks that a Norwegian process could well be used which involves mixing the ore with about one third coal and firing this in a rotary kiln. In this operation, about half of the oxygen is eliminated from the iron ore, yielding a prereduction product which is charged hot at about 2000° F. into the electric smelting furnace. The requisite amount of lime flux is added to the kiln. By prereducing the ore in this process, only about 1000 kw. per ton of iron is consumed in the basic electric furnace, and irons containing less than 0.03% sulphur can be produced. A furnace of 400-tons daily capacity can be built, using approximately 30,000 kw-hr., which should make pig iron for about $30 to $35 a ton, and produce about 150,000 tons of hot metal a year. Since the price of pig iron in British Columbia, which must be shipped long distances, is $80 to $90 a ton, this should be an attractive operation.

Another similar method of operating of this type is the McWane-McDowell Process wherein the ore is mixed with about one third its weight of coal, pelletized, and then sintered to prereduce it. While the author does not describe either of these processes, he does give a detailed account of the Strategic-Udy process which is almost a copy of the Norwegian process, which has been operating for five or six years with good results.

In conclusion, it seems as if an integrated steel plant in British Columbia is still a long way off, but sufficient steel could be made by the electric melting of scrap and pig iron produced at the Consolidated Mining and Smelting Co. at a very reasonable figure.

E. C. Wright

Hydrogen Embrittlement in Copper

Digest of "An Investigation of Hydrogen Embrittlement in Copper", by Einar Mattsson and Franz Schückher, *Journal*, Institute of Metals, Vol. 87, 1958-59, p. 241-247.

When copper containing oxygen is heated in an atmosphere containing hydrogen, the hydrogen diffuses through the metal and unites with the oxygen to form water vapor. This vapor cannot escape and remains at the point of formation exerting pressure on the copper. If the heating is continued, it can cause the pressure to reach values high enough to cause intercrystalline cracking along the grain boundaries. This cracking greatly reduces the mechanical properties of the metal.

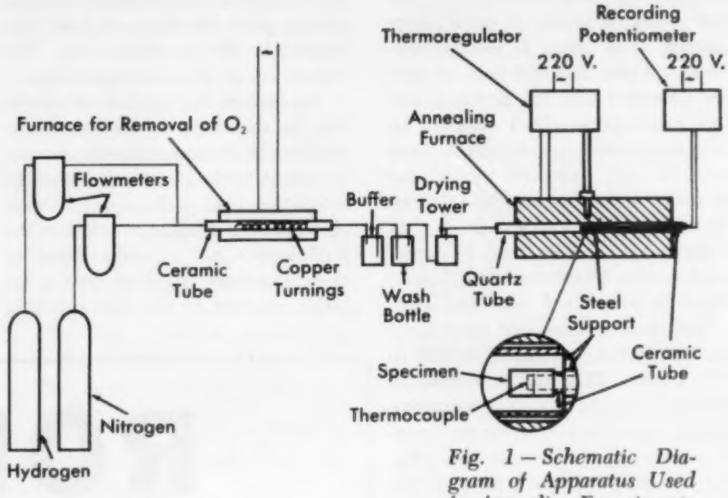

Fig. 1 – Schematic Diagram of Apparatus Used for Annealing Experiments

This problem is of great concern to industry inasmuch as the bright annealing of copper in a hydrogen atmosphere is becoming a very widespread practice. Therefore, it was decided to make a laboratory study of the various factors influencing hydrogen embrittlement, such as hydrogen pressure, annealing temperature and annealing time, to determine whether or not the cracking could be avoided.

The investigation was conducted by annealing specimens of tough pitch copper in a controlled atmosphere. The temperature, the time intervals, and the hydrogen content were varied, but only one factor was varied at a time. The apparatus used is shown schematically in Fig. 1.

The test procedure was as follows: Specimens were placed in a furnace tube and the air in the tube was flushed out with nitrogen containing 0.5% hydrogen. The tube was flushed at the rate of 3 l. of gas per min. until the oxygen content of the gas in the tube was reduced to 0.05%. After the tube was inserted in the hot furnace and the gas flow continued, furnace temperature was set at the desired level.

When the specimen temperature had stabilized, hydrogen concentration was increased to the desired value, and the annealing period was started. When annealing was over,

the tube was removed from the furnace for cooling, and the hydrogen concentration was adjusted to the initial value. As soon as the specimen dropped below 200° F., it was sectioned, polished and examined for signs of deoxidation and hydrogen embrittlement. During these tests, the hydrogen concentration was varied from 0.5 to 8%, the annealing time ranged from 1 to 5 hr., and the temperature ranged from 400 to 700° C. (750 to 1300° F.)

Test results indicated that when hydrogen is above 2%, the depth of embrittlement is proportional to the square root of the hydrogen concentration. Depth also varies directly as a function of the annealing temperature and the annealing time.

The results also revealed that at the beginning of the annealing period deoxidation took place through the diffusion of oxygen to the surface. Furthermore, the rate of deoxidation was independent of the hydrogen concentration in the atmosphere. During this time, which is called the incubation period, no cracking occurred. After the incubation period, deoxidation, accompanied by cracking, took place as a result of the penetration of hydrogen into the metal. During this stage, the deoxidation rate was dependent on the hydrogen content of the atmosphere.

It therefore appears that, during the incubation period, deoxidation was due to the diffusion of oxygen to the metal surface, but during the cracking period it was due to the penetration of hydrogen into the metal. Moreover, the transition from incubation to cracking occurs when the concentration gradient of oxygen toward the surface falls below a critical value.

As a result of this investigation, it was determined that, when bright annealing, the temperature and hydrogen concentration should be so selected that the annealing period does not exceed the incubation time. This signifies that copper with a high oxygen content should have a long incubation period, and copper with low oxygen should have a short incubation period. In addition, since the effects of repeated anneals are additive, the secondary anneals, if needed, should be shorter than the first.

BERNARD TROCK

(More digests on p. 204)

Al-Zn-Mg Alloys

Digest of "Hot Shortness and Mechanical Properties of Aluminum-Zinc-Magnesium Alloys", by W. Patterson and S. Engler, *Aluminium*, March 1959, p. 124-130.

THE TENDENCY of aluminum-zinc-magnesium alloys to crack when hot (hot shortness) was investigated in alloys with 0 to 10% zinc and 0 to 10% magnesium. The same alloy ranges were also tested with a constant addition of 0.5% copper. The results of these experiments can be summarized as follows:

1. Hot shortness of copper-free aluminum alloys is highest at about 7% zinc and 1% magnesium.

2. Hot shortness of alloys also containing copper is highest at about 4% zinc and 1.5 to 2% magnesium. With increasing zinc concentration, hot shortness remains fairly constant, and begins to drop off only when more magnesium is also added.

3. Most aluminum-zinc-magnesium alloys produced for commercial use also contain small amounts of iron. In addition, small quantities of titanium are included in the alloy for grain refining.

4. Addition of copper to aluminum, either by itself or with other elements, increases hot shortness; addition of iron reduces hot shortness.

Mechanical properties of alloys with 0 to 10% zinc and 0 to 10% magnesium were determined. Four test rods of each alloy were cast in sand and in a metal mold preheated to 400° F. Casting temperature was 200° F. above liquidus. To determine the effect of grain refinement, almost all melts were cast with and without grain refiner. In each instance, testing was delayed until ten days after casting. Results can be summarized as follows:

1. **Sand casting.** Highest tensile strength at about 4 to 10% zinc and 0 to 2% magnesium.

2. **Permanent mold casting.** Highest tensile strength at about 5 to 10% zinc and 0 to 3% magnesium. Ductility dropped as zinc and magnesium were increased.

These results showed the need for detailed examination of aluminum alloys containing 3 to 12% zinc and a little magnesium. The second series of experiments was made with alloys containing a constant 0.3%

copper and 0.8% iron, besides varying amounts of zinc and magnesium. The results were as follows:

1. **Sand casting.** Tensile strength increases proportionally in the range of 3 to 7.5% zinc and 0 to 0.3% magnesium. A range of approximately identical high tensile strength (37,000 to 38,000 psi.) lies between 7.5 and 12% zinc and 0.3 to 1% magnesium. Hardness increases with rising zinc and magnesium contents, reaching values slightly about Brinell 100 in the ranges of high tensile strength. Elongation drops from 20% in alloys with little zinc and magnesium to comparatively stable rates of 1 to 2% in the high tensile strength range of alloys.

2. **Permanent mold casting.** Here the tensile strength follows an abnormal pattern. It rises with the zinc content up to a concentration of 6%, reaches a maximum value at about 6 to 7.5% zinc and 0.3 to 0.5% magnesium, and begins to drop off when zinc and magnesium concentration becomes higher. However, if still more zinc and magnesium is added, the tensile strength begins to rise again and it would appear that it will continue to rise in concentrations of zinc and magnesium exceeding the percentage of the test alloys. Hardness and elongation vary as in sand castings.

3. **Effect of grain refining.** In the test alloys, grain refining did not improve the mechanical properties in all instances. In some cases it had a detrimental effect. However, improvement occurred more frequently than deterioration, both in sand castings and permanent mold castings. Improvement of tensile strength through grain refining was marked only in low-magnesium alloys (up to 1.5%). Elongation improved when the magnesium content was about 0.5%, but it deteriorated with grain refining in higher magnesium concentrations.

A thorough investigation of the mechanical properties and corrosion resistance of this type of aluminum alloy (conducted by L. W. Kempf and L. W. Eastwood and published by the American Foundryman's Soci-

Al-Zn-Mg Alloys . . .

ety in 1948) resulted in recommendation of an alloy of the following composition: 6.6% Zn, 0.33% Mg, 0.4% Cu, 0.25% Cr, 0.15% Ti, 0.15% Fe and 0.08% Si. The results of these experiments confirm that the composition of the alloy developed by Kempf and Eastwood gives optimum results.

K. C. SPENCER

Failure of Metals

Digest of "The Failure of Metals Under Load", by Hugh Muir, *Journal* of the Australian Institute of Metals, Vol. 3, May 1958, p. 44-50.

THE PAPER describes the different kinds of failures which occur in metals under load, and discusses the various approaches which have been made to analyze and to prevent failure. A brief summary of the metallurgical developments in the last centuries is given. It is shown how use of better materials for new purposes leads to new problems of failure – from the collapse of cast iron bridges in the 18th century to the recent Comet disasters.

In the past, the problem of failure was approached from the engineering side. The various modes of failure were classified phenomenologically, and the paper lists – though somewhat arbitrarily – ten different phenomena. However, it was difficult to understand the complex behavior of many materials. Progress was possible only after it was recognized that only four basic mechanisms are probably involved in failure. These are elastic deformation, plastic deformation, crack formation and crack propagation.

The new fundamental approach to the failure problem resulted from the successful application of the concept of solid-state physics to metallurgy. It was possible to describe the plastic behavior of metals in terms of imperfections of the crystal lattice on atomic scale such as dislocations, vacancies, and impurity atoms. It is hoped that the use of these new concepts will overcome some of the problems in failure.

A review of the various research institutions and research programs in physical metallurgy in postwar Australia is given. Investigations of fundamental nature are concentrated mainly along two lines: the measurement of stored energy in plastically deformed metals, and the study of the basic mechanism involved in the various modes of failure. A detailed description of five investigations dealing with the mechanisms of failure then follows. These are:

1. Investigation of the elastic limit in steels, and its dependence on heat treatment and other variables. This dependence is strikingly different from that of the yield strength and ultimate tensile strength.

2. Investigation of the mechanism of brittle failure, and, as a further consequence, production of ductile chromium.

3. Investigation of fragmentation

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Sub-Zero	SZH653	6.5	−85° F.	−75° F.	60"	28"	42¾"	47"	15"	16"
Sub-Zero	SZHC657	6.5	−140° F.	−125° F.	60"	28"	42¾"	47"	15"	16"
Rivet Cooler	RSZ503	5.0	−30° F.	−20° F.	42"	28"	41"	30"	16"	18"

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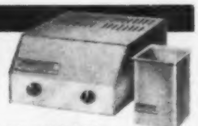

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(subgrain formation) during creep deformation at elevated temperature levels.

4. Interpretation of intercrystalline crack formation during creep. One of the possible mechanisms is the condensation of vacancies at grain boundaries.

5. Investigation of the mechanism of fatigue failure, especially work on work softening and crack formation under fatigue conditions.

G. SCHOECK

Welding in Red China

Digest of "Development and Application of Welding in the People's Republic of China", *Zvaranie*, June 1959, p. 177-179.

DEVELOPMENT of heavy industry is one of the major objectives of communist China. Though of prime importance for speeding up this development, welding on any appreciable scale has been in use only during the last five years. Great progress has been made in this period. In 1958 the number of power stations, steel mills and mines increased by 200 to 1300% compared to 1957 (more than the total of construction projects completed in the first five-year plan). The use of welding in the building of heavy industrial equipment has increased on the same scale.

At the end of 1958, a National Welding Conference was held in which five groups were formed and given the task of promoting the use of welding in 11 Chinese cities. Welding speeds up the production of turbines, hydraulic presses, boilers and other heavy equipment. The next objective is to increase the use of automatic and semi-automatic welding equipment with flux, and to develop CO_2 welding. Semi-automatic welding produces three times more than manual welding, automatic welding is ten times faster

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Lockheed Aircraft Corp.

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Lockheed Aircraft Corp.

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New Techniques for Processing Materials

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Stanford University

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Saturday Morning, Feb. 6, 1960

Metallurgical and Welding Problems in the Chemical and Petroleum Industries

Chairmen: *John W. Parks* and
Robert D. Switters,
Standard Oil Co. of California

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By *George A. Nelson*, Shell Development Co.

Notch Sensitivity of Carbon Steels at Ambient Temperatures
By *Earl R. Parker*, University of California

Field Welding and Annealing of Air Hardening Steels
By *Robert L. Skaggs*, Standard Oil Co. of California

New Techniques for Forming Materials

Chairman: *Jess W. Wilson*
Stanford Research Institute

Application of Shear Spinning to the Fabrication of Solid Propellant Rocket Cases
By *L. E. Zwissler*, Aerojet-General Corp.

Spark Machining, a New Technique in Fabrication
By *D. L. Curtis*, Japax America Corp.

Solution of Fabrication Problems by Explosive Forming
By *L. Zernow*, Aerojet-General Corp.

Fairmont Hotel, San Francisco, Site of Golden Gate Metals Conference

Welding . . .

than the manual method, and welding with a CO_2 atmosphere is, for certain types of work, twice as effective as automatic welding with flux.

In China, semi-automatic welding is used not only for the production of parts subjected to minor stresses, but also for welding high-pressure vessels. Automatic welding has been used successfully on vertical plates in ship building and on heavy boiler construction.

Preheating has been used extensively in the welding of heat resisting, heatproof and hard materials (castings). Great advances have also been made in welding processes for nonferrous metals. The aircraft industry welds aluminum and aluminum alloys. Nonferrous metals are welded also with an argon atmosphere.

Friction welding, resistance welding, hot and cold pressure welding, and flame welding have been used in solving different problems, such as fusing aluminum to copper. In 1958 several types of friction welding machines were built. This process is rapidly finding more applications and has the advantages of low current consumption. Dimensions of the parts which can be welded by one typical model of this machine are listed in Table I. The stationary piece can be of any desired length. Maximum length of the rotating piece is 6¼ in. and it turns at 2880 rpm. Motor capacity is 4.5 kw.

Table I – Typical Dimensions for Friction Welding

Material	Maximum Diameter	Maximum Cross Section
Aluminum with aluminum	1 3/16 in.	1 sq.in.
Aluminum with copper	1	¾
Copper with copper	1	¾
Steel with steel	1	¾
Aluminum with steel	1	¾

China also produces equipment for all other types of welding: Generators and transformers for manual arc welding; several types of resistance welding machines (for example, automatic tube welders); semi-automatic machines for welding with flux; equipment for the manufacture of arc welding electrodes (for example, a hydraulic press of Chinese design for pressing coated electrodes); welding guns and other equipment.

In 1957 the first Welding Research Institute was established in Harbin. Welding research is also conducted by the Chinese Academy for Science, a number of government departments, universities and industrial organizations. A monthly publication, *Hanjie (Welding)* has been published since the beginning of 1957. China's welding experts were educated in China, the U.S.S.R., and in Czechoslovakia.

K. C. Spencer

Behind the By-lines

The author of "An English Metallurgist Looks at Progress in Metal Forming", D. V. Wilson, became interested in the potential value of advances in metals physics to problems in practical metallurgical production after the war, and from 1947 to 1950 carried out research at the University of Sheffield on the cold working of steel. He received his doctorate from the university in 1950 and since that time has been a lecturer in the department of industrial metallurgy at the University of Birmingham. Senior lecturer since 1957, his recent research has been in the fields of plasticity, strain aging and metal forming. A graduate of Cambridge University in 1938, he started work for the British Non-Ferrous Metals Research Assoc. but on the outbreak of war was seconded to the Royal Ordnance Factory where he stayed until 1947.

D. V. Wilson

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While Mr. Hübscher was born in England, he was educated in Switzerland, and for three years after graduation, he was an assistant to Prof. F. P. Treadwell at the Federal Technical High School at Zurich, and for another three years was at Mond Nickel Co.'s refinery in South Wales. Returning to Switzerland in 1914, he joined the staff of George Fischer Limited at Schaffhausen and was soon put at the head of the steel castings division in the research laboratory when it was founded in 1922, and in this position took a leading part in the development of melting and heat treating practices for such new steels as low-alloy nickel-chromium steels and high-alloy corrosion resisting steels. Since 1953 he has been metallurgical assistant to the manager of the George Fischer steel foundries.

Hans E. Hubscher

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The facts for the article on high-temperature alloys in the U.S.S.R. were gathered by A. G. Guy during a six-month stay at the Baikov Institute of Metallurgy in Moscow under a National Science Foundation grant. A professor of metallurgical engineering at Purdue University, Dr. Guy spent the academic year 1958-59 on sabbatical leave with his family (a wife and two teenage daughters) in Europe. Originally hoping to spend a full year in the Soviet Union on a scientific exchange, his stay was reduced to six months due to visa difficulty; however, he had an opportunity to spend three weeks in Russia as a member of the Exchange Commission on Engineering Education while waiting for the exchange to be arranged.

Behind the Bylines . . .

Although his college training at the University of Chicago was in chemistry, his interest in metallurgy led him to graduate work in that field and in 1946 he received his doctorate in metallurgy from Carnegie Institute of Technology. After

A. G. Guy

several years in industry, he joined the faculty of North Carolina State College, taught for four years, then spent two years as chief of the metallurgy branch of the Office of Ordnance Research in Durham, N. C., before coming to Purdue as associate professor in 1952; he was named full professor on the faculty in 1955.

One of his spare-time activities is keeping in touch with Russian work in his field and he is familiar to *Metal Progress* readers as a digester of Russian metallurgical papers.

F. Howitt and I. H. Jenks, authors of the report from Canada on improved aluminum alloys for bright anodizing, are both with Aluminium Laboratories Limited in Kingston, Ont. Mr. Howitt, a graduate of Sheffield University in England, has been on the staff of the Aluminium Limited Group since 1936 when he joined Northern Aluminium Co. Limited in the United Kingdom. In 1954 he came to Canada and a year later transferred to Aluminium Laboratories Limited where he is head of the physical metallurgy division. Mr. Jenks received his schooling at Mount Allison University, Sackville, New Brunswick, and after several years with the Aluminum Co. of Canada transferred to the associated research company, Aluminium Laboratories Limited, as a technical writer; since 1947 he has been head of the publications division.

Alan Blainey's report on hot pressing powders in England is based on work carried out at the United Kingdom Atomic Energy Research Establishment in Harwell, England. Educated in Manchester and Liverpool, he worked on light metals with High Duty Alloys, Ltd. and on powder metals with Hard Metal Tools Ltd. and Parnall Aircraft Ltd., until joining A.E.R.E. in 1946. After nine years of work on nuclear metals and fuel elements, he transferred to the research staff of the Anglo-American Corp. of South Africa Ltd. He is now working in Johannesburg.

The report from Norway on electropolishing of columbium and tantalum is the joint effort of O. J. Krudtaa and K. Stokland of the Central Institute for Industrial Research in Oslo. Mr. Krudtaa has worked as metallurgical engineer at the Institute since 1957, specializing

O. J. Krudtaa

in metallography. After graduating from the Göteborg Tekniska Institut in 1954, he continued his education on a scholarship given by the Royal Norwegian Council for Scientific and Industrial Research, studying materials testing at the Oslo Institute for Testing Materials and metallurgy and metallography at the Max-

Planck-Institut for Metal Research.

As for the co-author, Mr. Stokland's field is inorganic chemistry. He received a chemical degree from the Norwegian Institute of Technology and was a laboratory instructor in inorganic chemistry at the Institute for three years. Then in 1946 he joined the Norwegian Defense Research Establishment where he organized the department for in-

K. Stokland

organic chemistry, corrosion and metallography, and also worked on the refining of uranium for the Norwegian Institute of Atomic Energy. Since 1951 he has been head of the inorganic chemistry department at the Central Institute.

The interesting survey on Russian educational methods in the metallurgical field by Ian G. Slater is the result of a recent trip to Russia to study higher technological education and industry there. At present head of the department of metallurgy in the College of Advanced Technology in Birmingham, England, Dr. Slater has had varied experience both in academic work and in industry. He graduated in metallurgy and joined the staff of the British Non-Ferrous Metals Research Assoc., working on a number of problems related to aluminum alloys and the casting and rolling of nonferrous metals generally. In 1936 he joined the Royal Naval Dockyard in Portsmouth as chief metallurgist, completing his career with the Royal Naval Scientific Service in 1949 as director of operational research. He was subsequently appointed director of research and development to the alu-

Ian G. Slater

minum division of Tube Investments Ltd. and five years ago returned to the academic world.

H. P. Tardif has been physical metallurgist and head of the materials laboratory for the Canadian Armament Research and Development Establishment in Valcartier, Que., since 1953, specializing in explosive forming. After graduating from Laval University in Quebec in 1949, he received a Quebec Department of Mines Scholarship for a year of

H. P. Tardif

study at Carnegie Institute of Technology, and then went to Ottawa as a metallurgist at the Bureau of Mines. Awarded an Athlone Fellowship, he was engaged in research work in the department of industrial metallurgy at the University of Birmingham, England, for two years, receiving his doctorate in 1953; on his return to Canada, he took up his present post.

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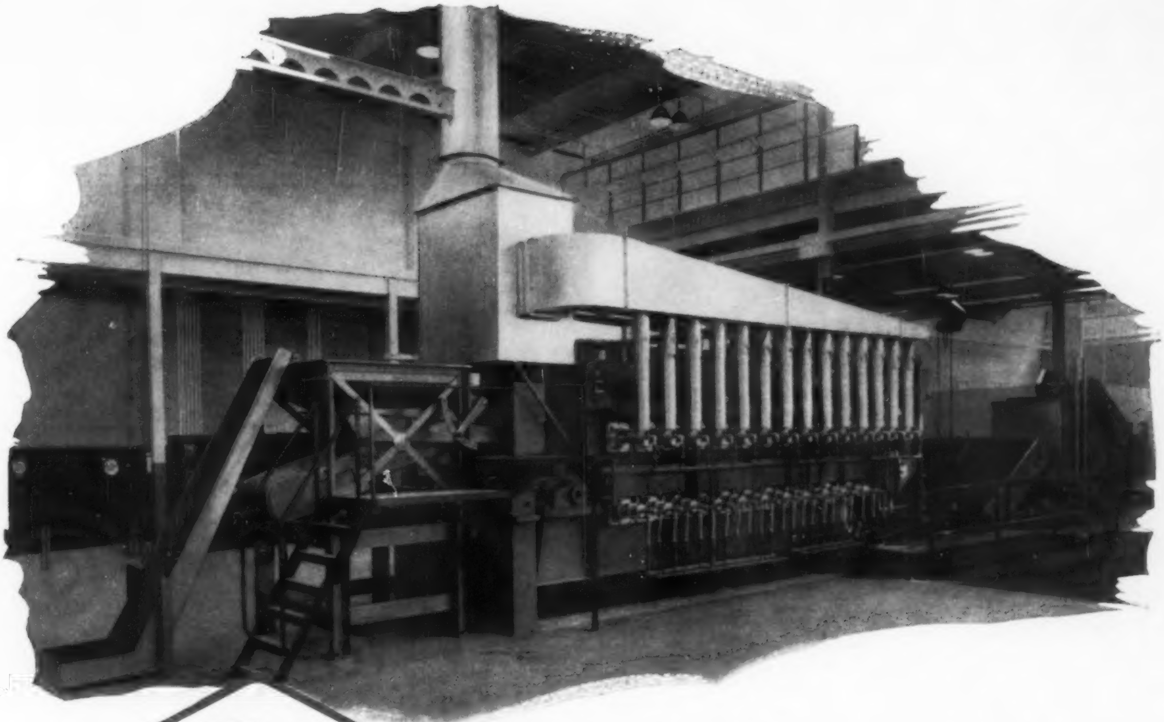

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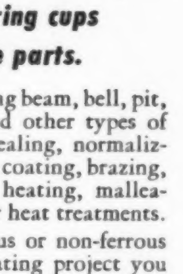

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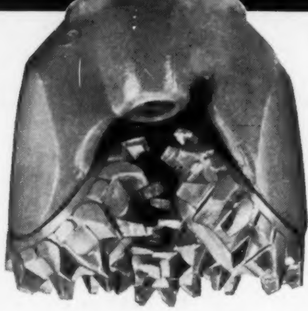

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